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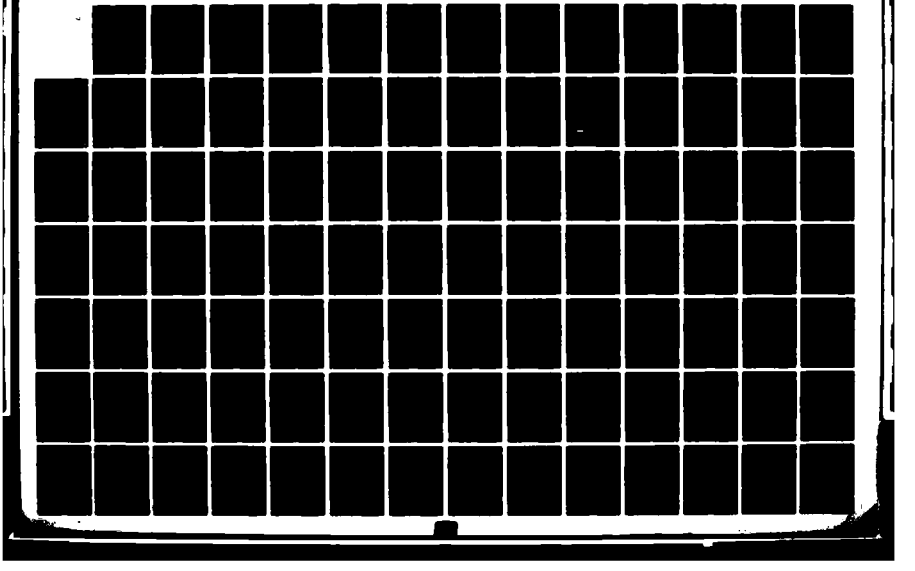

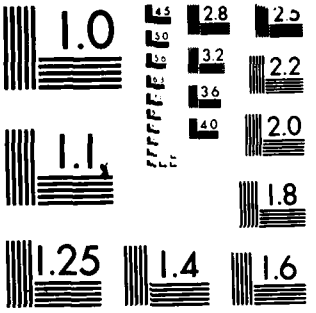

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Final Contract Report N00014-83-K-0305

April 1984

(12)

EXPERIMENTAL DETERMINATION OF THE WAVE ELEVATION NEXT TO A MODEL OF THE SL-7

AD-A142 320

Prepared under contract for:

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The experimental results presented in this report describe the relative water elevation along the side of a model of the SL-7. Three relative motion components were measured and the results discussed. The components are the following: one due to steady forward speed, one due to forced oscillation, and one due to incident waves. Capacitance wave probes were attached to the model at ten locations starting at the forward perpendicular and extending to mid-ships. The forced oscillation or radiation relative motion was measured for three different forward speeds. The reative motion associated with the incident wave -

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was measured in both regular and irregular, transient waves. In all cases, the wave records were Fourier analyzed on line, between runs. The results are graphed as functions of wavelength to ship-length ratios and again as functions of longitudinal hull location. A number of repeatability tests and linearity checks were run.

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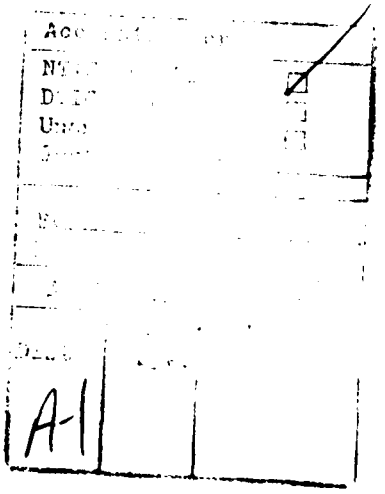

Experimental Determination of the Wave Elevation Next to a Model of the SL-7

by

A.W. Troesch, T.B. Kelly, B.K. King

INTRODUCTION

The deficiencies in the methods used in predicting deck-wetness have been known for some time. Hoffman and MacLean (1970) noted that the usual relative motion analysis yielded poor correlation between experiment and theory. Takaishi, et.al. (1972) also conducted relative wave elevation experiments and stated that the disagreement between measured and calculated values was relatively small for bow and stern seas but large in quartering seas. More recently, Andrew and Lloyd (1980) compare the calculated average deck-wetness interval with sea trial results and report that the theory is inadequate. Oliver (1983), in a report to the Ship Structure Committee, has formulated a non-linear theory that includes above-water line effects. However, some of the assumptions in Oliver's model are suspect and the computer analysis can take hours of CPU time. More rational approaches to theoretical estimates are given by Beck (1982), Lee (1982), and Lee, O'Dea and Meyers (1982). While all of these theoretical models address fundamental aspects of the deck wetness problem, they will have difficulty including effects such as increase wave-steepness, large amplitude motions, and non-wall-sided vessels. Consequently the use of model experiments with actual ship hull forms is expected to remain an important part in the prediction of lost freeboard and deck-wetness. See, for example, O'Dea (1983), O'Dea and Jones (1983), and Webster and Zhu (1983).

The experimental results presented in this report describe the relative water elevation along the side of a model of the SL-7. Any analysis of lost freeboard and relative motion will divide the total response into various

components. Generally these will be a component due to steady forward speed, one due to body motion, and one due to incident waves. As shown in this report, all three of these components were measured and the results are discussed. Capacitance wave probes were attached to the model at ten locations, starting at the forward perpendicular and ending at mid-ships. The forced oscillation or radiation relative motion was measured for three different forward speeds. The relative motion associated with the incident waves was measured in both regular and irregular, transient waves. In all cases, the wave records were Fourier analyzed on line, between runs. The results are graphed as functions of wavelength to ship length ratios and again as functions of longitudinal hull location. A number of repeatability tests and linearity checks were run. These are also described in the text. The large amount of data collected and presented represents a useful tool in determining the relative motion of SL-7 type hull forms.

TECHNICAL DISCUSSION

Relative motion is defined as the distance from the mean waterline of the vessel to the instantaneous elevation of the water surface. Generally, the total displacement of the water at any point along the hull may be attributed to a number of components. Under a linear hypothesis, the following components are assumed to be additive:

i) Steady forward motion wave profile.

ii) Incident wave.

iii) Diffracted wave.

iv) Radiated or forced oscillation wave.

All of the above components were measured in the experiments described in this report. The relative motion at ten stations were found through the use of capacitance wave probes. The steady wave profile was determined at three Froude numbers, 0.1, 0.2, and 0.3 respectively.

The relative motion resulting from the diffracted wave and incident wave were measured together. In this type of experiment, the model is restrained from moving in heave, pitch, sway, roll, yaw, and surge. With the model rigidly attached to the carriage, it is then towed through waves generated by a wave maker located at the far end of the tank. Typically the incident wave is measured at some distance in front of the carriage. The wave probes on the model record the sum of the incident and diffracted waves. In the experiments described in this report, the incident plus diffracted wave relative motion was measured for a Froude number of 0.2 in regular and transient waves. The transient wave tests were conducted in a manner similar to that described by Takezawa and Takekawa (1976).

The radiated wave is the wave train generated by rigid body motion. In this series of tests, the model is oscillated in heave or pitch by some type of shaker mechanism. The relative motion is then defined in terms of a ratio of water displacement to hull displacement. Results for both heave and pitch at Froude numbers 0.1, 0.2, and 0.3 are included.

EXPERIMENTAL APPARATUS AND TECHNIQUES

Towing Tank and Wavemaker

The University of Michigan, Department of Naval Architecture and Marine Engineering maintains a towing tank of 190.7m (360 ft) in length, approximately 6.7m (22 ft) wide at the normal waterline, and 4.3m (14 ft) deep. The towing carriage is capable of speeds up to 4.88m (16 ft/sec), and models up to 9.1m (30 ft) in length have been tested.

A vertically oscillating wedge-shaped steel tank is installed as a wavemaker. It is electrically actuated, and gives acceptably linear response over a wavelength band from 0.9 to 5.5m (3 to 18 ft), with wave heights up to approximately 0.15m (0.5 ft), depending somewhat on the wavelength involved. For nominally sinusoidal regular waves, input to the electric control system is from an oscillator. Alternatively, random waves can be generated using prerecorded input derived from a given sea spectrum.

Forced-Oscillation Mechanism

The forced-oscillation device was developed in connection with recent ABS-supported experimental work. The device is capable of forcing oscillation in either pitch or heave. The mechanism is electrically actuated, with its frequency controlled by varying the speed of the electric drive. The amplitude of the impressed motion could be varied by discrete increments, using a scotch yoke mechanism.

Model

The model used in this study was that of the SL-7 class containership. Dimensions, weights, hull-form coefficients, and pitch gyradii for the ship and model are shown in Table I. A body plan of the ship is shown in Figure 1.

TABLE I: SL-7 Hull Particulars

	Ship	Model
LOA m(ft)	288.5(946.6)	3.607(11.83)
LBP m(ft)	268.4(880.5)	3.355(11.01)
Beam m(ft)	32.16(105.5)	0.402(1.319)
Draft @ LCF m (ft)	9.94(32.6)	0.124(.408)
Trim by stern mm(ft)	43.0(0.14)	0.53(0.0018)
LCG Aft of O m(ft)	11.7(38.4)	0.146(.480)
Displacement MT(LT)	48364(47500)	0.0945(.0928)
Pitch Radius of Gyration	0.21 LBP	0.21 LBP

Heave and Pitch Measurements

For the forced-oscillation tests, the vertical displacement at a known location of the model was measured by a linear voltage differential transformal (LVDT). This displacement, then, could be easily related to heave and pitch motions.

Wave Probes

Two types of wave probes were used in the experiments. For the diffraction tests, the incident wave was measured by a Wesmar Ultrasonic Level Monitor, Model LM4000 sonic wave probe. It was fitted under the forward end of the towing carriage, approximately 2.1m (7 ft) ahead of the model. For the relative motion measurements, a capacitance-type wave probe was used. It is described below.

Capacitance wave probes have certain advantages over other commonly used water level measurement devices, i.e. resistance and sonic probes. As de-

scribed by Luft (1968), they require no aging, show only moderate sensitivity to dirt, and several probes can be operated close to each other simultaneously without interference. In the past, disadvantages included the choice of material used for the dielectric and a relatively complex excitation circuit.

While carrying out the terms of an ONR/GHR contract (N00014-78-C-0109) contract, a different method of constructing and using capacitance probes was found. Following an IC design suggested by Pipil and Curzon (1979) for use in measuring standing or capillary waves in a basin, a modified circuit was produced for the ship motion experiments. The circuit is simple, inexpensive, and reliable. It is built around an IC chip used in automobile tachometers. Ten such circuits were manufactured for the experiments described in this report.

The probes were made of 32 gauge magnet wire and supported away from the model by small poles. The distance that the wires were from the hull surface averaged 3-4mm (0.12-0.16 in). The non-linear gain of the probes due to the changing hull shape was factored into the computer program that did the data reduction.

Data Recording

The entire measurement system was calibrated twice a day during the experimental program. A schematic showing the instrumentation set up is shown in Figure 2. On each run, twelve channels of data were sampled. Ten were capacitance wave probes, one was the incident wave probe or shaker LVDT, and one was the carriage speed tachometer. The records were Fourier analyzed and the results printed out between the runs. Interim plots were kept in order to identify general trends and bad data.

EXPERIMENTAL RESULTS

The test matrix for the SL-7 model is shown in Table II. The regular waves covered a range of wavelength to ship length ratios of 0.25 to 1.9. Some of the data points were lost due to infrequent hardware difficulties. These are represented by gaps in the curves. Only one forward speed was used for the diffraction experiments.

TABLE II: Model Test Conditions

	Froude number			Regular waves	Transient waves
	0.1	0.2	0.3		
Diffraction		X		X	X
Radiation	X	X	X	X	

The longitudinal location of the wave probes are shown in Figure 3. Also shown are the directions of positive heave, pitch, and relative motion. Heave is defined as the vertical displacement of the model measured at midship, and pitch as the angular rotation about an axis located at the intersection of the water plane and the midship section. Heave is positive up, pitch is positive bow down, and relative motion is positive for the water surface above the mean water line. (Positive heave produces a negative relative motion.)

The actual tests results are presented in tabular and graphical form. In the following figures, the crosses represent the unfaired data. (The points are connected by straight line segments for visual effect.) The following non-dimensional scheme was used:

Forced Heave -

$$\text{Relative motion} = \frac{\text{relative motion amplitude}}{\text{heave amplitude}}$$

Phase Angle = Arg(rel. motion) - Arg(heave)

Forced Pitch -

$$\text{Relative motion} = \frac{\text{relative motion amplitude}}{\text{amplitude of vertical displacement at Station 20}}$$

Phase Angle = Arg(rel. motion) - Arg(pitch)

Diffraction -

$$\text{Relative motion} = \frac{\text{relative motion amplitude}}{\text{incident wave amplitude}}$$

Phase Angle = Arg(rel. motion) - Arg(incident wave)

The argument of the incident wave is zero when a wave trough is at midships.

The actual data points for the various runs are listed in Table III. The magnitudes for the time dependent relative motions are normalized as described above. The approximate excitation amplitude listed in the table refers to the heave amplitude for forced heave, the amplitude of the vertical displacement at station 20 for forced pitch, and the incident wave amplitude for the diffraction tests. The units of the excitation amplitudes are inches. The steady state wave profiles in inches are also listed.

The figures that follow are the plotted results listed in Table III. The relative motion is given as a function of wavelength to ship length for various stations, and again as a function of longitudinal location along the hull for various wavelength to ship lengths. This method of cross plotting helps illustrate a number of interesting points. The order that the plots

appear is shown below:

i) Forced Heave . Fn = 0.1

ii) Forced Pitch . Fn = 0.1

iii) Forced Heave . Fn = 0.2

iv) Forced Pitch . Fn = 0.2

v) Forced Heave . Fn = 0.3

vi) Forced Pitch . Fn = 0.3

vii) Forced Heave . Fn = 0.2 (linearity test)

viii) Forced Pitch . Fn = 0.2 (linearity and repeatibility tests)

ix) Diffraction . Fn = 0.2 (regular waves)

x) Diffraction . Fn = 0.2 (transient test, three different runs)

xi) Steady Wave Profiles.

CONCLUSIONS

There are large increases in the relative motion magnitudes for Fn = 0.1 when wavelength to ship length equals 1.445. The parameter that compares the wave period to hull speed, i.e. (frequency of encounter)*(vessel speed)/(gravitational constant), has a value of 1/4 for this case. This implies that the radiated wave speed and hull speed are nearly equal and tank-wall reflection becomes a major problem. Consequently, the results for Fn=0.1 with wavelengths to ship lengths ratios equal to and greater than 1.44[illegible] are contaminated with tank-wall reflection effects. For the higher Froude numbers, the parameter was greater than 1/4 in all wavelengths tested.

The forced pitch records show that the point of rotation, as far as relative motion is concerned, is at station 12, rather than station 10. The plots show that the relative motion magnitude reaches a minimum there. Also, the phase angles change 180° from stations 14 to 10 indicating when the relative motion at station 14 is positive, it is negative at station 10.

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Both repeatability and linearity checks were run for the forced oscillation tests. The repeatability appeared to be adequate. For the linearity tests, the heave amplitude was increased by 50% and the pitch amplitude was more than doubled. No significant difference was observed for heave, but the larger pitch motions seemed to reduce the pure pitch relative motion response amplitude operator. This was particularly true in the bow region where interactions between the hull shape, steady state wave, and time dependent wave are more pronounced.

The transient test results were inconclusive. Three different runs were made, each meeting the wave group in a different location in the tank. The overall comparison with the regular wave results is not good. More work is needed in this area to identify the cause of disagreement.

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Table III: Tabulated Results of Relative Motion Experiments

DATA FOR FORCED HEAVE FN=0.1
THE APROXIMATE EXCITATION AMPLITUDE IS 1.00
MAGNITUDES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.883	0.737	0.911	0.895	0.759	0.731	0.788	0.749	0.784	0.878	0.990
1.445	1.059	1.593	1.839	2.065	1.877	1.751	1.715	1.538	1.434	1.409
1.152	0.907	1.109	1.242	1.209	1.173	1.099	1.055	1.120	1.249	1.163
0.865	0.865	1.038	1.202	1.177	1.180	1.165	1.085	0.972	0.973	1.027
0.734	0.956	1.128	1.290	1.256	1.235	1.230	1.141	1.043	1.059	1.119
0.634	0.882	1.035	1.221	1.205	1.211	1.194	1.145	1.088	1.139	1.217
0.376	0.882	1.005	1.221	1.229	1.322	1.340	1.392	1.451	1.532	1.575
0.257	0.887	0.969	1.141	1.147	1.248	1.393	1.532	1.743	1.754	1.754

PHASE ANGLES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.883	171.063	169.923	180.523	179.612	174.922	172.621	172.381	170.391	172.270	178.230
1.445	119.304	115.878	129.111	146.235	160.198	166.222	173.605	199.789	215.022	228.856
1.152	171.292	166.061	167.110	175.719	181.188	183.597	185.756	191.385	208.644	227.503
0.865	168.136	162.232	164.698	169.915	176.961	183.117	192.414	202.340	208.056	204.743
0.734	168.054	162.585	162.277	168.519	174.641	180.583	190.694	201.166	206.638	201.670
0.634	168.224	162.100	162.586	168.052	176.317	182.933	195.039	206.484	211.280	204.736
0.376	170.425	162.632	154.700	162.908	169.736	180.484	196.042	205.920	205.818	194.216
0.257	167.665	159.775	148.545	156.635	162.835	171.755	185.485	197.955	197.665	182.666

DATA FOR FORCED PITCH FN=0.1
THE APROXIMATE EXCITATION AMPLITUDE IS 1.44
MAGNITUDES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.883	1.323	1.638	1.427	1.275	1.077	0.977	0.846	0.383	0.151	0.260
1.445	1.585	2.105	1.922	1.740	1.370	1.104	0.912	0.371	0.408	0.638
1.152	1.010	1.285	1.158	1.102	0.964	0.763	0.701	0.384	0.231	0.414
0.865	1.008	1.270	1.148	1.129	1.004	0.814	0.713	0.273	0.076	0.146
0.734	0.942	1.201	1.075	1.079	0.956	0.783	0.671	0.273	0.091	0.166
0.634	1.003	1.262	1.143	1.116	1.023	0.824	0.746	0.339	0.134	0.132
0.376	1.002	1.255	1.147	1.144	1.083	0.939	0.909	0.485	0.177	0.175
0.248	0.983	1.147	0.947	0.965	0.884	0.857	1.109	0.502	0.127	0.244

PHASE ANGLES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.883	162.553	160.073	172.693	178.352	179.522	176.371	192.181	202.721	248.020	338.680
1.445	155.804	156.268	178.491	188.885	199.478	202.262	220.215	276.019	348.722	19.386
1.152	172.812	162.761	169.420	170.999	175.578	182.447	185.966	199.085	261.564	340.313
0.865	174.426	162.922	169.008	170.915	176.411	187.847	199.374	209.250	249.876	355.603
0.734	173.724	162.805	165.637	168.929	178.191	188.693	199.224	217.606	265.928	351.430
0.634	172.694	160.900	165.576	167.042	177.637	180.903	197.509	215.794	236.150	354.116
0.376	171.365	157.772	156.180	159.538	171.206	179.024	199.392	211.760	212.668	7.176
0.248	168.720	149.682	138.134	142.476	158.588	174.730	186.302	193.974	190.487	15.159

Table III: Tabulated Results of Relative Motion Experiments (con't.)

DATA FOR FORCED HEAVE FN=0.2
THE APROXIMATE EXCITATION AMPLITUDE IS 1.00
MAGNITUDES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.503	0.894	1.260	1.086	1.192	1.331	1.101	1.012	1.130	1.063	1.057
1.503	0.901	1.259	1.110	1.198	1.333	1.192	1.012	1.110	1.040	1.040
1.154	0.890	1.257	1.068	1.176	1.349	1.103	0.986	1.176	1.127	1.157
0.867	0.861	1.147	1.027	1.150	1.357	1.132	1.068	1.270	1.252	1.304
0.766	0.866	0.926	1.001	1.132	1.341	1.204	1.240	1.353	1.383	1.424
0.618	0.904	0.967	1.008	1.166	1.395	1.418	1.493	1.480	1.561	1.634
0.379	0.907	0.913	0.911	1.066	1.284	1.510	1.666	1.963	1.991	1.899
0.248	0.865	0.872	0.668	0.683	0.810	1.192	1.625	2.126	2.052	1.757

PHASE ANGLES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.503	174.412	168.971	166.400	167.589	175.628	179.497	184.206	197.605	202.264	201.403
1.503	175.282	169.961	166.620	168.379	176.488	180.707	179.860	197.885	201.964	201.223
1.154	173.336	166.822	164.098	165.735	174.071	176.757	183.734	200.340	204.906	203.583
0.867	175.734	169.240	165.096	167.012	174.887	178.773	188.349	204.964	210.500	205.846
0.766	172.902	168.204	161.385	163.556	170.637	171.118	186.459	204.040	209.982	204.283
0.618	171.401	165.762	157.592	159.733	166.253	171.784	183.684	203.935	208.985	202.216
0.379	169.645	165.635	157.085	156.085	161.855	168.415	185.995	199.775	196.985	184.076
0.248	167.461	167.209	153.156	148.513	157.660	167.857	185.984	189.691	188.538	181.025

DATA FOR FORCED PITCH FN=0.2
THE APROXIMATE EXCITATION AMPLITUDE IS 1.44
MAGNITUDES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.852	1.138	1.109	1.121	1.109	1.133	0.964	0.681	0.317	0.044	0.224
1.503	1.070	1.116	1.099	1.098	1.146	0.975	0.766	0.323	0.048	0.210
1.154	1.082	1.181	1.083	1.081	1.180	1.001	0.0	0.353	0.094	0.217
0.867	1.062	1.139	1.065	1.070	1.204	0.990	0.692	0.397	0.119	0.200
0.766	1.054	1.126	1.041	1.064	1.209	1.031	0.792	0.417	0.133	0.171
0.618	1.070	1.147	1.035	1.138	1.191	1.080	0.870	0.485	0.179	0.154
0.379	0.998	1.069	0.898	1.022	1.077	1.014	1.025	0.646	0.211	0.261

PHASE ANGLES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.851	173.464	174.938	169.021	172.075	179.948	183.172	194.555	200.269	256.932	1.026
1.503	174.662	173.371	166.730	170.269	178.188	180.907	188.166	201.765	246.134	2.313
1.154	175.206	174.092	166.258	171.145	176.471	181.347	119.154	212.100	268.646	353.573
0.867	172.994	172.650	162.846	169.312	170.287	177.013	196.709	212.154	254.440	354.156
0.766	169.042	169.154	159.335	165.936	165.677	175.108	193.409	210.240	241.222	355.393
0.618	169.551	168.102	158.872	161.343	165.783	174 814	195.374	210.945	234.355	357.476
0.379	171.695	165.015	155.905	154.095	159.025	164.885	186.475	204.795	196.115	13.296

Table III: Tabulated Results of Relative Motion Experiments (con't.)

DATA FOR FORCED HEAVE FN=0.3
THE APROXIMATE EXCITATION AMPLITUDE IS 1.00
MAGNITUDES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.831	0.963	0.971	1.159	1.309	1.340	1.504	1.446	1.358	1.248	1.171
1.541	0 873	0.889	1.005	1.171	1.200	1.374	1.337	1.256	1.152	1.100
1.156	0.950	0.865	1.119	1.279	1.327	1.557	1.568	1.546	1.431	1.426
0.867	0 973	0.917	1.106	1.233	1.278	1.562	1.598	1.661	1.602	1.623
0.751	0.974	0.839	1.070	1.204	1.263	1.555	1.639	1.738	1.784	1.800
0.633	1.018	0.809	1.094	1.198	1.253	1.586	1.706	1.973	2.033	2.023
0.381	0.949	0.808	0.950	0.990	1.140	1.426	1.747	2.405	2.337	2.125

PHASE ANGLES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.831	173.072	167.281	167.840	165.909	171.238	179.727	188.876	198.005	202.864	201.053
1.541	166.080	158.805	161.969	159.463	165.878	173.992	181.557	194.181	200.485	200.250
1.156	174.859	167.813	167.036	166.470	171.484	180.178	191.882	204.455	210.519	209.443
0.867	168.340	162.417	162.523	160.340	167.537	173.703	186.040	200.896	208.673	204.230
0.751	168.444	163.558	162.432	160.926	167.990	171.684	186.148	202.112	210.236	203.340
0.633	167.462	167.386	163.039	161.612	169.656	173.439	186.313	202.316	208.069	200.173
0.381	166.125	165.987	155.319	155.442	163.304	166.776	180.779	186.901	185.013	171.975

DATA FOR FORCED PITCH FN=0.3
THE APROXIMATE EXCITATION AMPLITUDE IS 1.44
MAGNITUDES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.831	1 065	1.230	1.084	1 120	1.059	0.996	0.778	0.351	0.074	0.202
1.541	1.017	1.142	1.053	1.083	1.026	0 996	0.787	0.330	0.059	0.230
1.156	0.984	1.165	1.036	1.037	0 991	1.015	0.793	0.389	0.169	0.311
0.867	1.027	1.190	1.056	1 040	1.010	1.089	0.881	0.487	0.172	0.231
0.751	1.013	1.167	1.064	1.027	1.012	1.107	0.881	0.531	0.194	0.188
0.633	1.010	1.125	1.034	0.987	0.999	1.094	0.968	0.595	0.240	0.171
0.391	0.990	0.985	0.795	0.753	0.773	0.752	1.206	0.732	0.211	0.346

PHASE ANGLES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.831	174.722	175.031	172.680	169.879	173 078	185.497	199.796	205.755	256.984	2.173
1.541	173.070	172.715	170.089	166.963	171.008	182 762	197.097	205.711	264.725	6.620
1.156	177.369	176.833	172.996	169.710	175.384	187.508	192.212	229.305	292.049	347.263
0.867	172.850	171.527	167.443	163.580	169.787	178.543	190.780	216.486	259.983	337.910
0.751	171.234	167.398	163.032	159.696	167.760	175.004	185.498	211.072	248.176	339.240
0.633	172.012	167.166	162.489	161 252	168 936	172.509	189.483	210.176	238.589	347.573
0.391	168.579	167.740	162.100	163.340	168.151	172.841	174.571	202.512	208.552	359.872

Table III: Tabulated Results of Relative Motion Experiments (con't.)

DATA FOR DIFFRACTION FN=0.2
THE APROXIMATE EXCITATION AMPLITUDE IS 1.00
MAGNITUDES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.845	0.920	1.068	1.206	1.153	1.195	1.311	1.113	1.107	1.043	0.955
1.503	0.916	1.045	1.227	1.121	1.183	1.217	1.199	1.082	1.029	0.929
1.154	0.948	0.978	1.271	1.131	1.242	1.366	1.278	1.133	1.076	0.960
0.926	1.013	1.082	1.300	1.150	1.302	1.352	1.276	1.150	1.088	0.968
0.766	0.973	1.158	1.265	1.098	1.273	1.356	1.259	1.139	1.066	0.960
0.650	0.964	1.121	1.254	1.105	1.283	1.347	1.255	1.160	1.086	0.970
0.406	1.003	1.274	1.232	1.149	1.339	1.426	1.410	1.333	1.244	1.103
0.261	0.983	1.372	1.097	1.065	1.352	1.433	1.583	1.336	1.244	1.122

PHASE ANGLES

1.845	273.164	258.918	254.071	250.125	253.548	240.422	232.095	225.679	206.762	185.306
1.503	295.502	279.471	271.830	268.209	271.818	255.357	245.406	233.005	210.154	184.043
1.154	330.546	312.852	301.288	296.915	299.781	278.847	266.004	246.620	217.306	184.743
0.926	4.159	346.903	330.077	325.990	326.604	303.068	287.342	256.845	218.899	177.883
0.766	51.002	29.614	9.895	4.876	4.397	332.908	316.219	279.990	234.412	185.653
0.650	86.586	68.094	43.603	35.861	34.050	1.148	339.537	294.016	240.914	183.713
0.406	247.787	214.181	179.716	163.671	149.505	102.880	65.225	344.259	257.714	165.139
0.261	138.814	93.065	44.107	18.488	350.730	275.512	217.533	86.015	310.217	166.848

DATA FOR FORCED HEAVE FN=0.2
THE APROXIMATE EXCITATION AMPLITUDE IS 1.50
MAGNITUDES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.852	1.020	0.858	1.142	1.197	1.289	1.255	1.155	1.102	1.024	0.975
0.514	0.947	0.981	1.017	1.115	1.302	1.419	1.418	1.590	1.626	1.685
0 306	0.913	0.941	0.928	1.056	1.206	1.489	1.600	1.968	1.836	1.706

PHASES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.852	348.713	349.107	344.311	345.936	351.590	357.644	1.969	12.603	14.977	12.881
0.514	349.548	347.489	337.930	339.661	341.791	353.982	8.623	22.374	21.214	11.195
0.306	349.407	343.364	334.731	329.947	334.414	339.711	353.698	3.325	4.842	358.699

Table III: Tabulated Results of Relative Motion Experiments (con't.)

DATA FOR FORCED PITCH FN=0.2
THE APROXIMATE EXCITATION AMPLITUDE IS 3.09
MAGNITUDES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.852	0.911	1.012	0.942	0.978	0.941	0.797	0.495	0.349	0.110	0.090
1.506	0.904	1.007	0.935	0.966	0.961	0.812	0.570	0.371	0.138	0.073
1.154	0.894	1.001	0.897	0.948	0.961	0.825	0.661	0.379	0.162	0.110
0.867	0.868	0.983	0.873	0.927	0.941	0.836	0.712	0.418	0.198	0.085
0.766	0.886	0.995	0.862	0.945	0.966	0.859	0.755	0.490	0.257	0.076
0.618	0.868	0.976	0.834	0.916	0.948	0.833	0.814	0.539	0.297	0.074
0.379	0.864	0.880	0.759	0.815	0.862	0.872	0.949	0.734	0.359	0.032

PHASES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.852	169.640	172.080	168.190	171.790	180.360	185.690	192.280	199.760	207.550	1.510
1.503	170.200	170.550	166.840	170.310	179.190	184.250	191.280	202.120	213.130	345.020
1.154	170.120	171.410	166.710	170.500	179.310	186.530	198.890	214.250	237.090	326.840
0.867	165.170	168.920	163.380	167.950	175.960	183.790	198.910	216.070	234.060	310.360
0.766	167.750	167.130	162.230	166.390	173.890	180.980	199.540	215.490	227.860	283.180
0.618	167.870	166.700	161.610	165.510	172.700	181.900	198.660	218.110	227.310	266.220
0.379	166.320	162.450	158.800	159.200	162.560	172.320	189.690	210.070	203.930	69.100

DATA FOR FORCED PITCH FN=0.2
THE APROXIMATE EXCITATION AMPLITUDE IS 1.44
MAGNITUDES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.852	0.941	1.211	1.099	1.131	1.115	0.784	0.561	0.277	0.029	0.173
1.154	0.995	0.954	1.062	1.097	1.117	0.739	0.514	0.278	0.060	0.195

PHASES

LAMBDA/L	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
1.852	170.120	174.830	169.420	171.210	179.850	183.280	194.430	201.960	241.000	9.250
1.155	175.270	171.910	163.830	166.190	174.040	183.280	197.420	215.080	281.510	3.330

STEADY WAVE PROFILES

FN	STA.20.0	STA.19.5	STA.19.0	STA.18.5	STA.18.0	STA.17.0	STA.16.0	STA.14.0	STA.12.0	STA.10.0
0.1	0.087	-0.127	0.128	0.004	0.090	0.049	0.048	0.022	-0.017	-0.033
0.2	0.509	0.516	0.084	-0.113	-0.063	0.318	0.365	0.021	0.013	-0.148
0.3	0.646	1.197	0.835	0.623	0.477	0.497	0.502	0.071	-0.087	-0.396

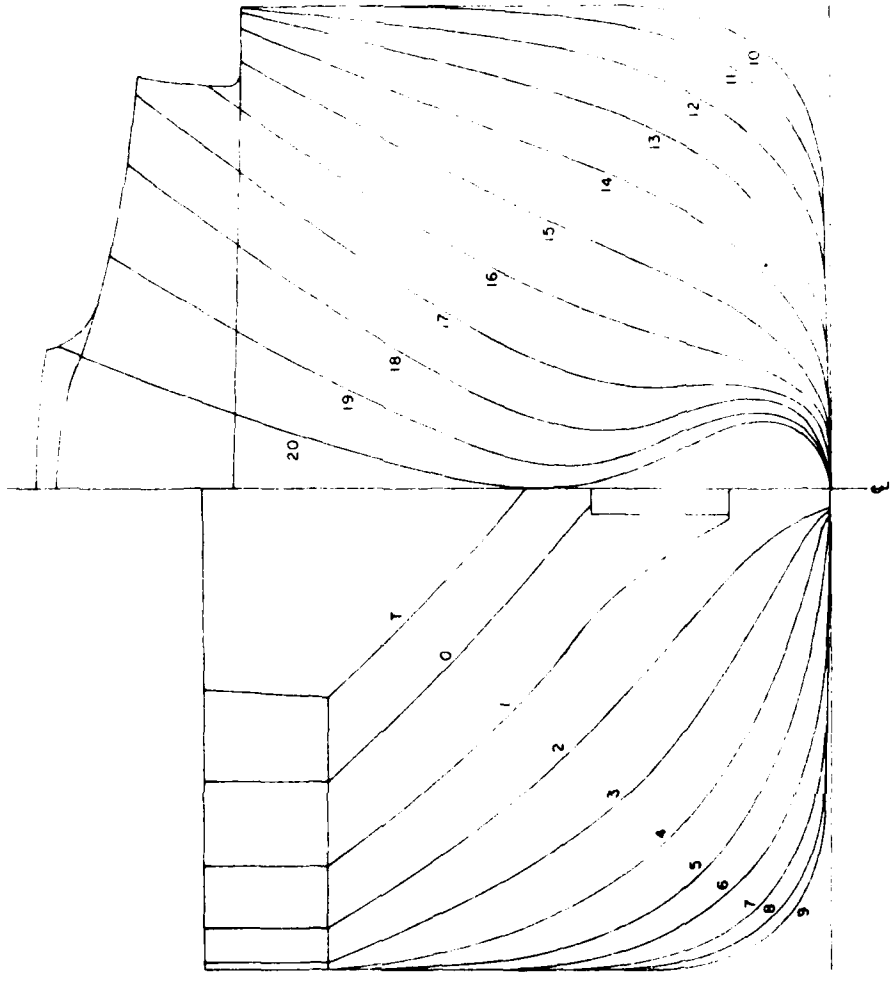


Figure 1: Body Plan of the SL-7 (with station numbers)

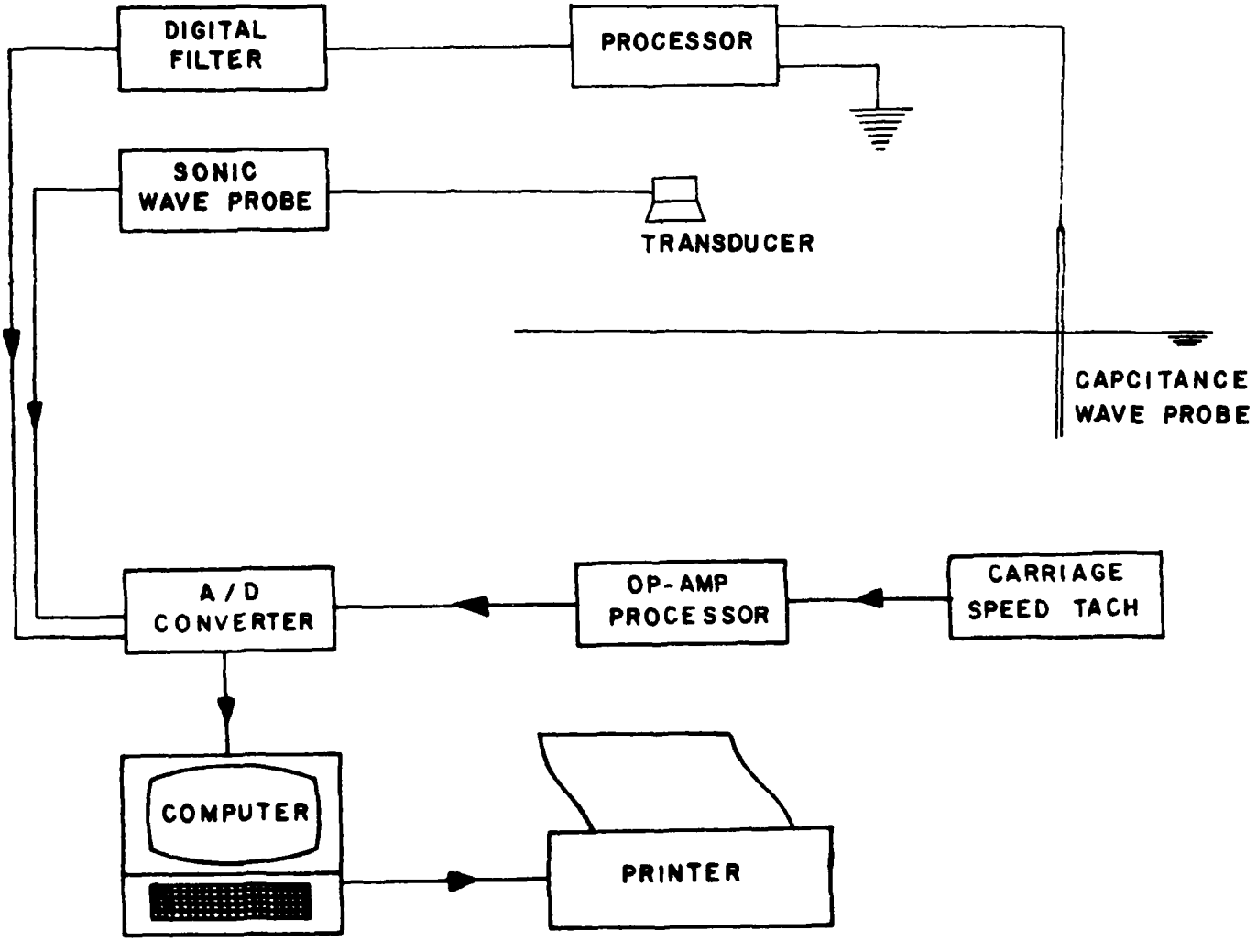


Figure 2: Signal Processing/Data Analysis Configuration

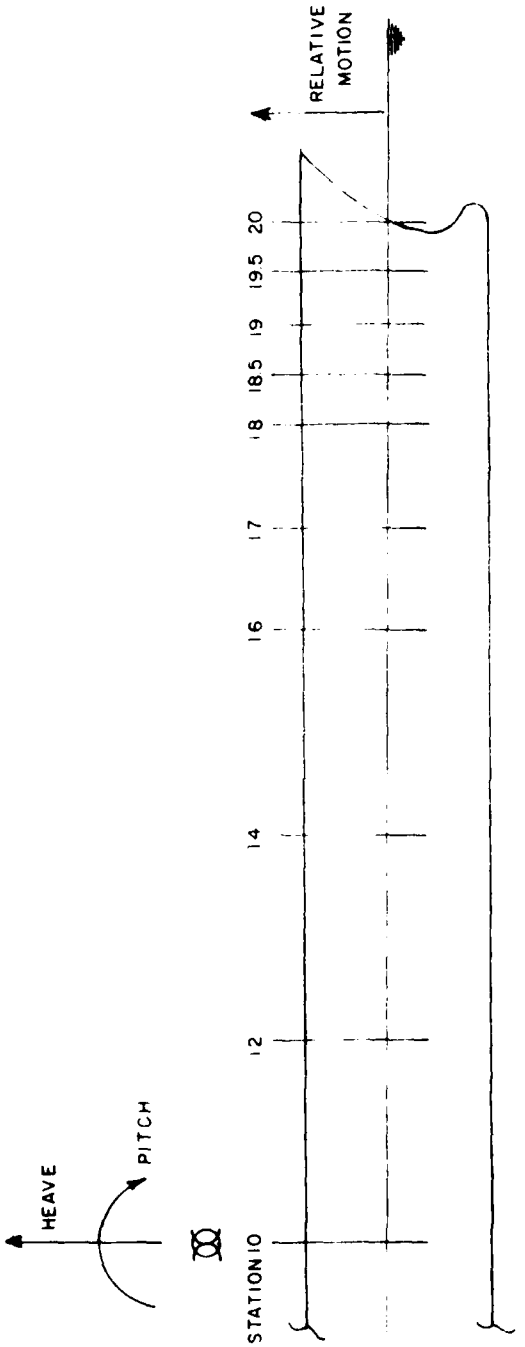
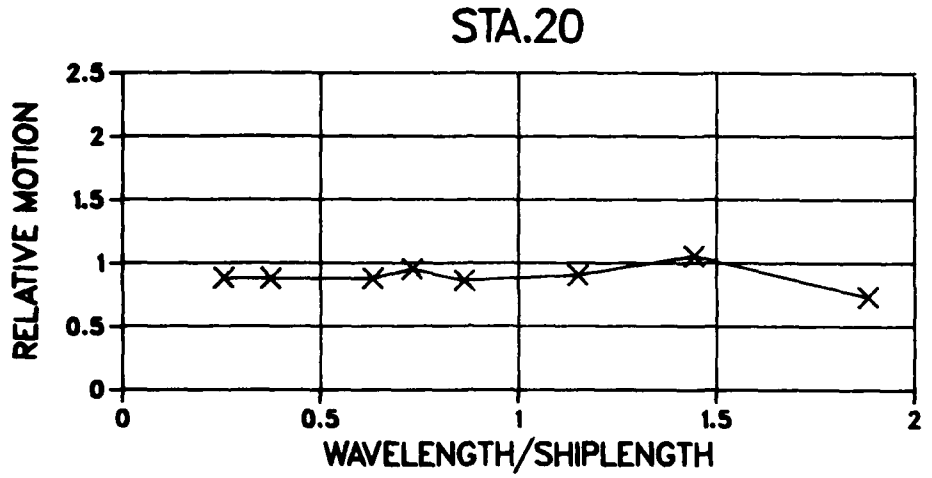
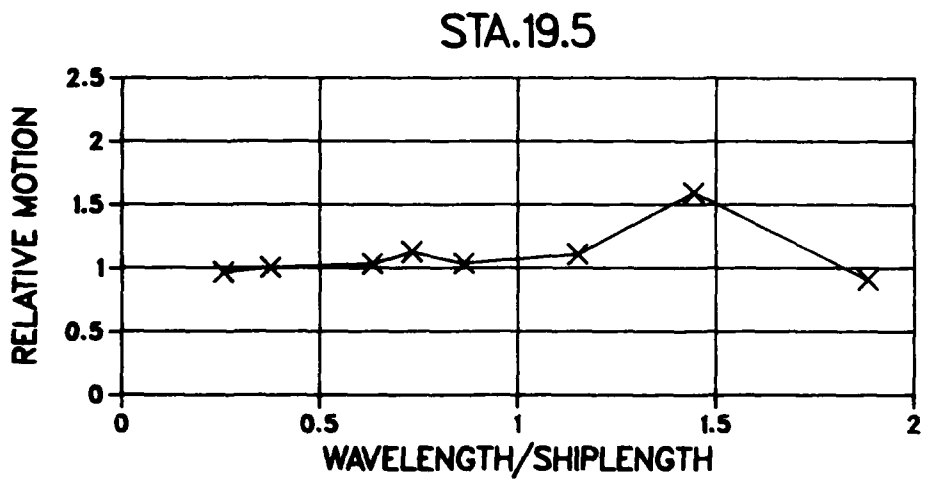
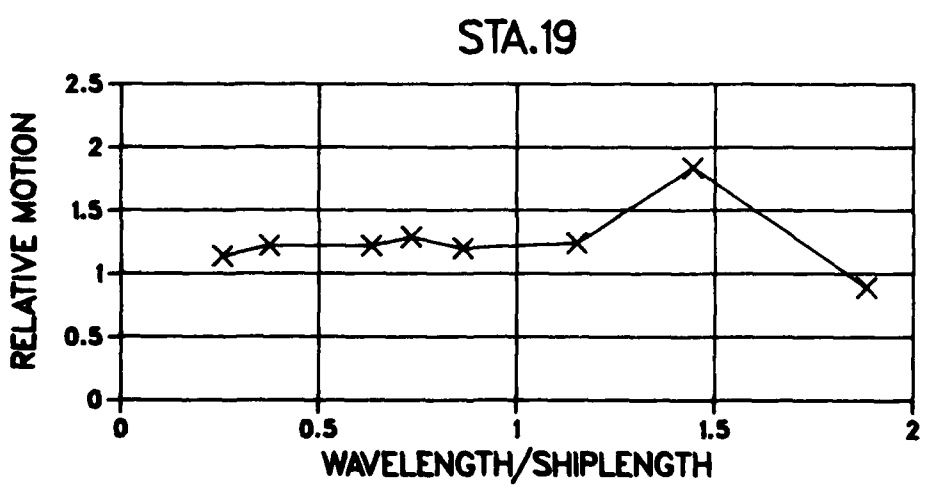


Figure 3: Location of Wave Probes and Definition of Response

FORCED HEAVE. FN=0.1

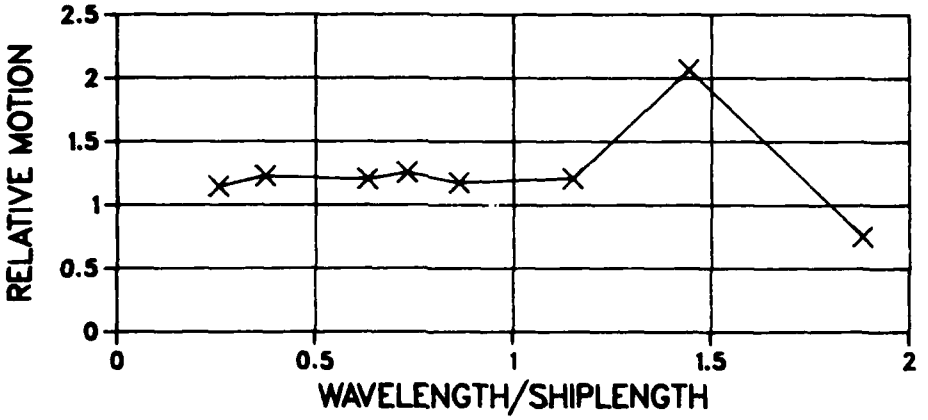




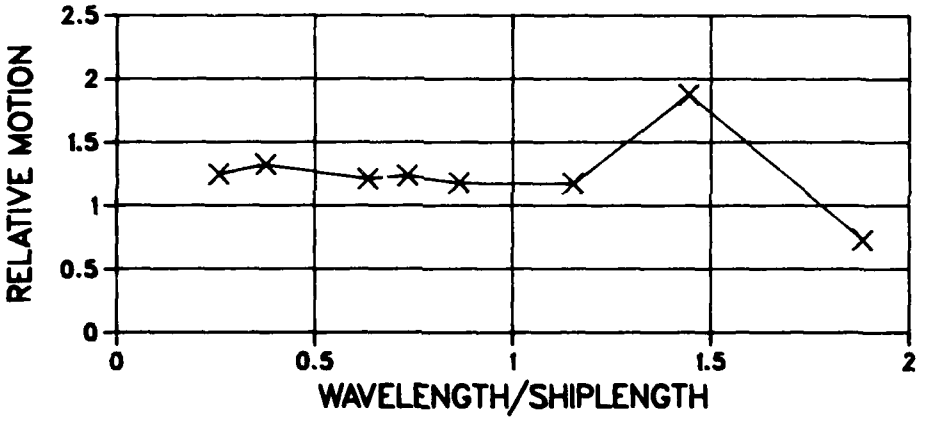


FORCED HEAVE. FN=0.1

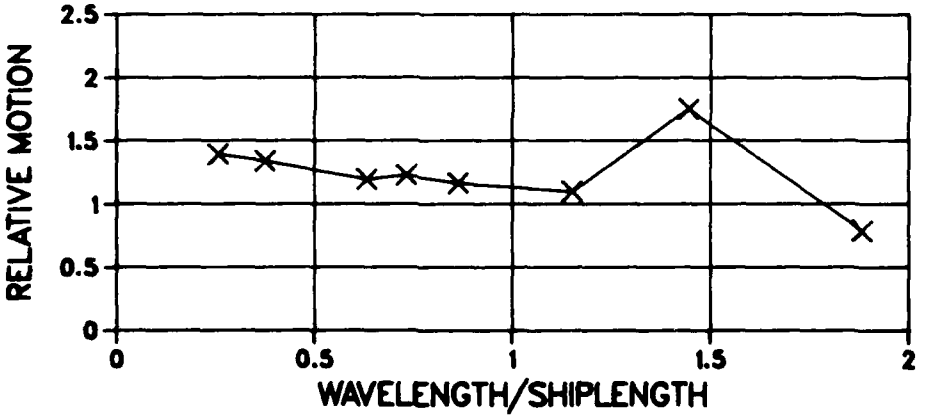
STA.18.5



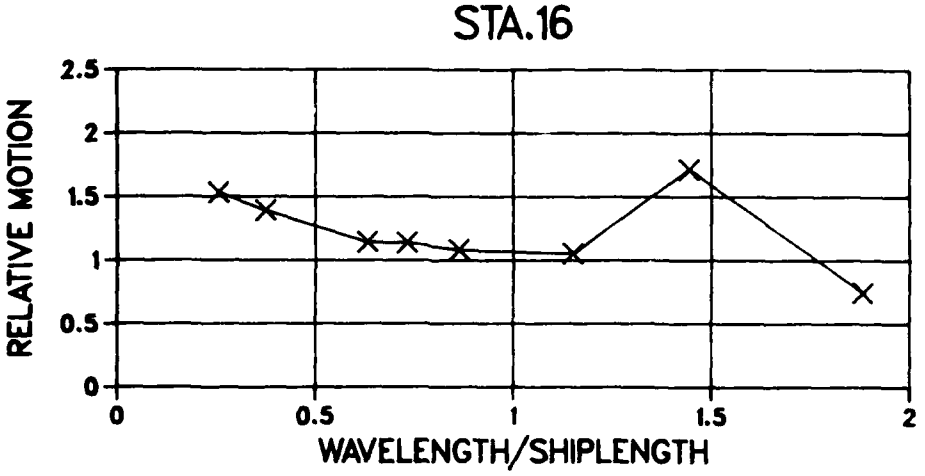
STA.18

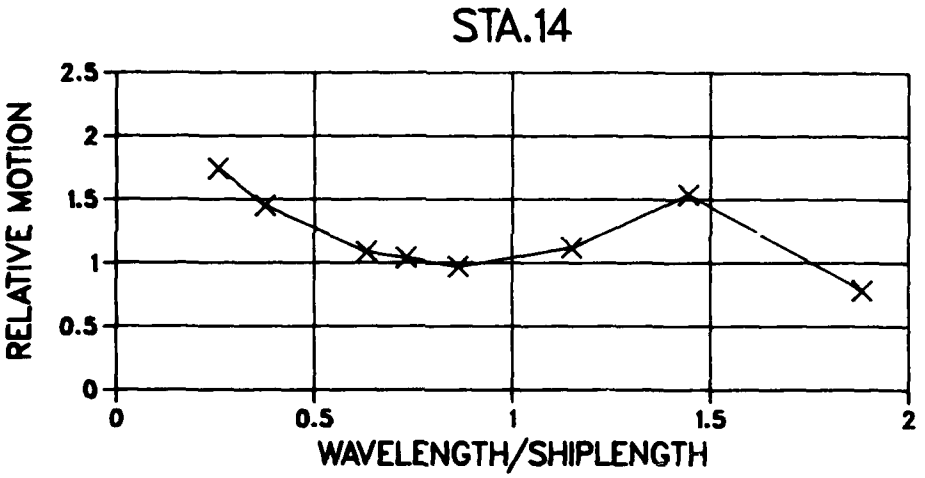


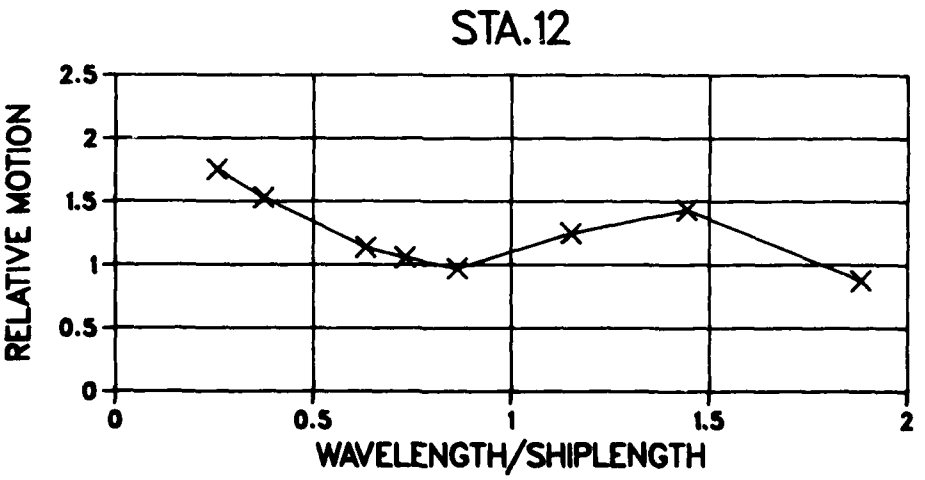
STA.17



FORCED HEAVE. FN=0.1

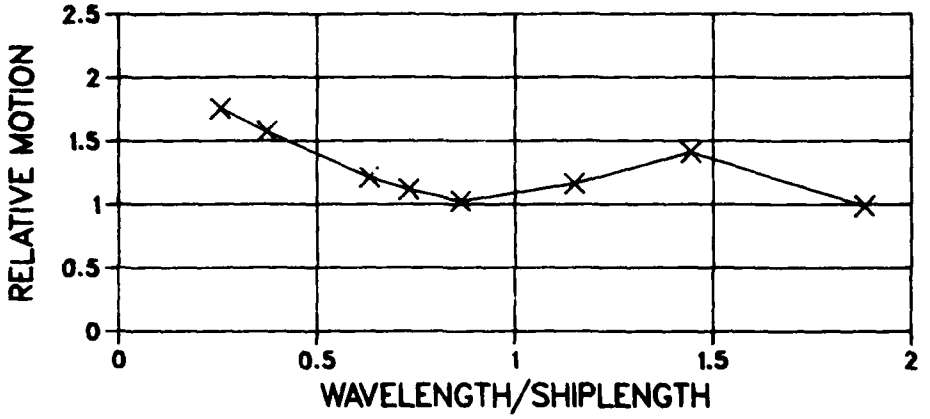






FORCED HEAVE. FN=0.1

STA.10



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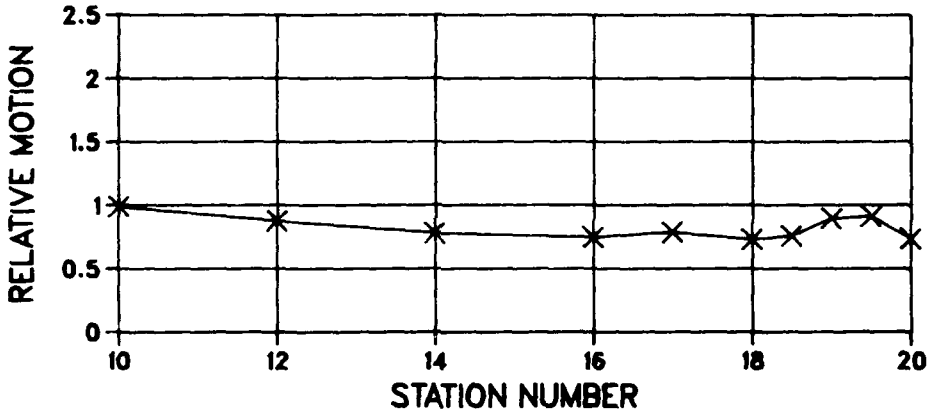

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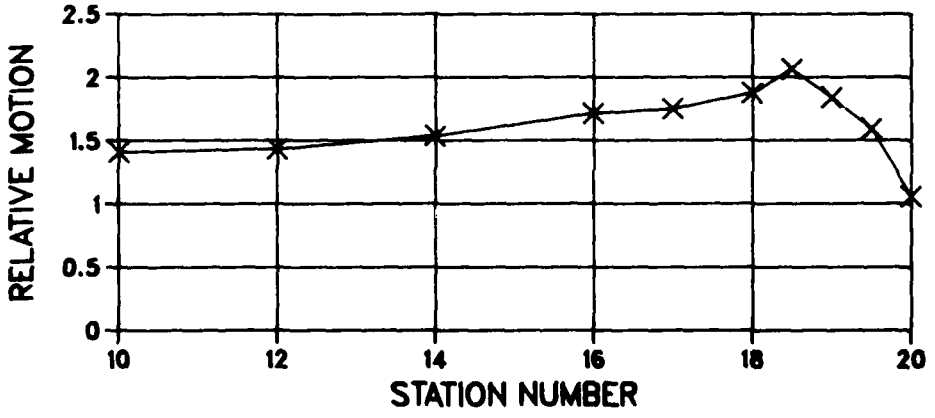
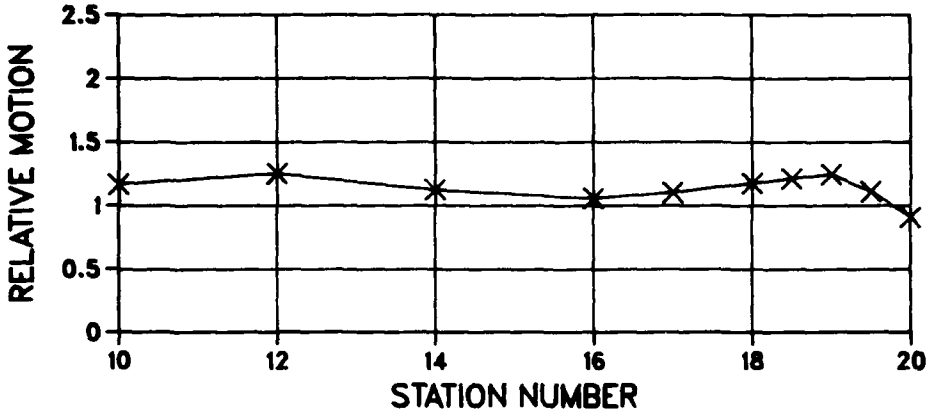
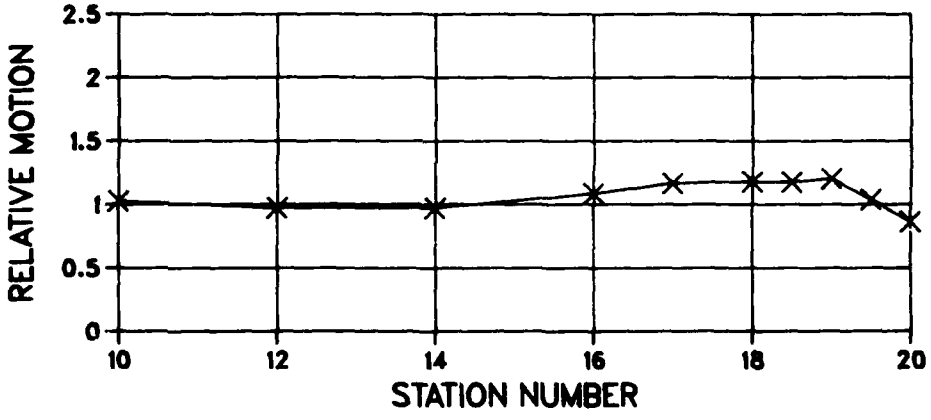


FORCED HEAVE. FN=0.1

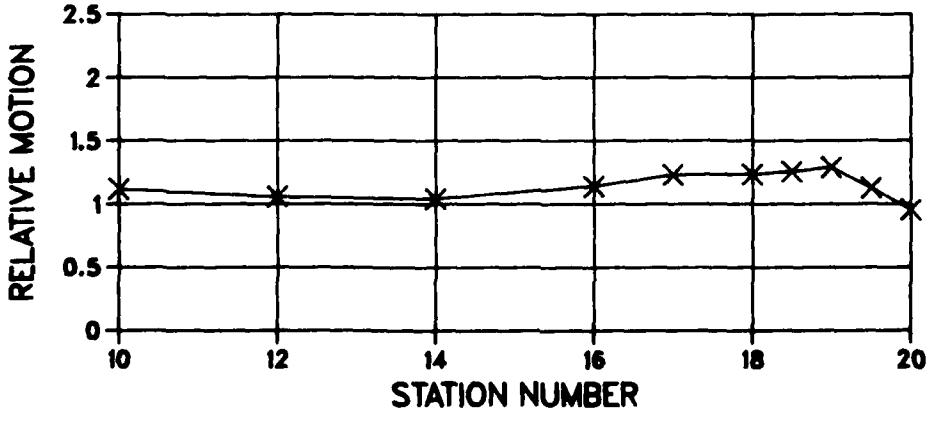
LAMBDA/L =1.152



LAMBDA/L =0.865

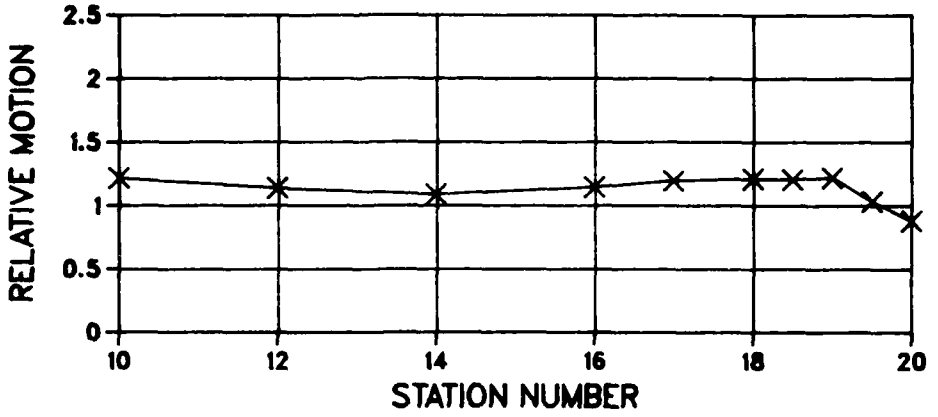


LAMBDA/L =0.734



FORCED HEAVE. FN=0.1

LAMBDA/L =0.634



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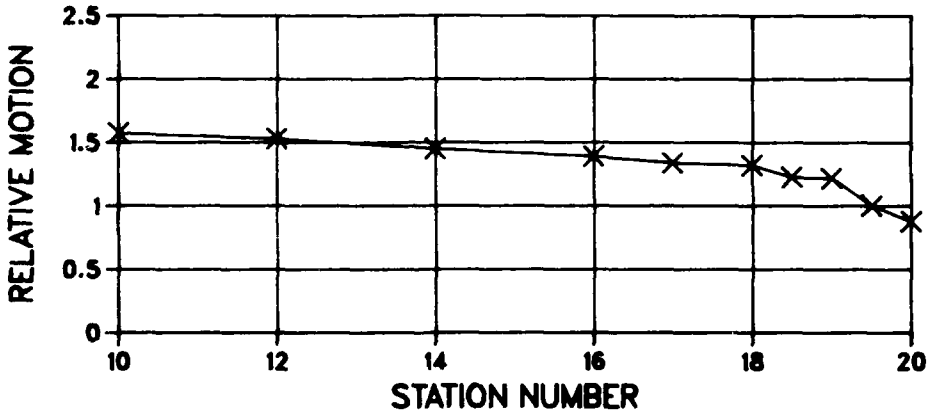

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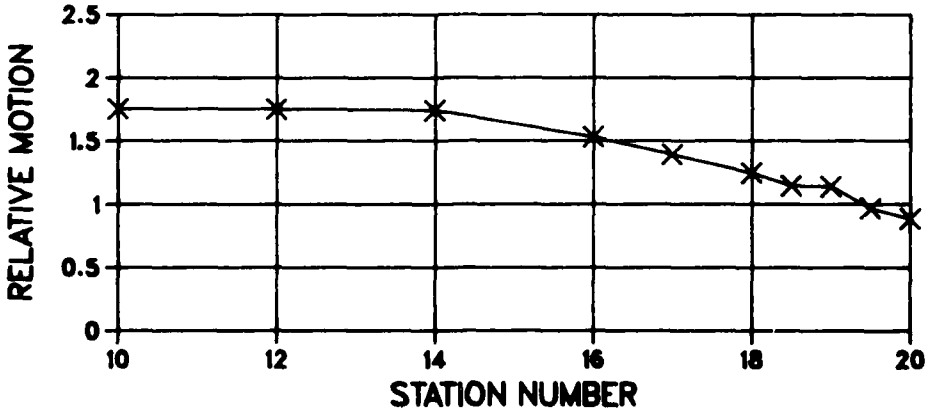
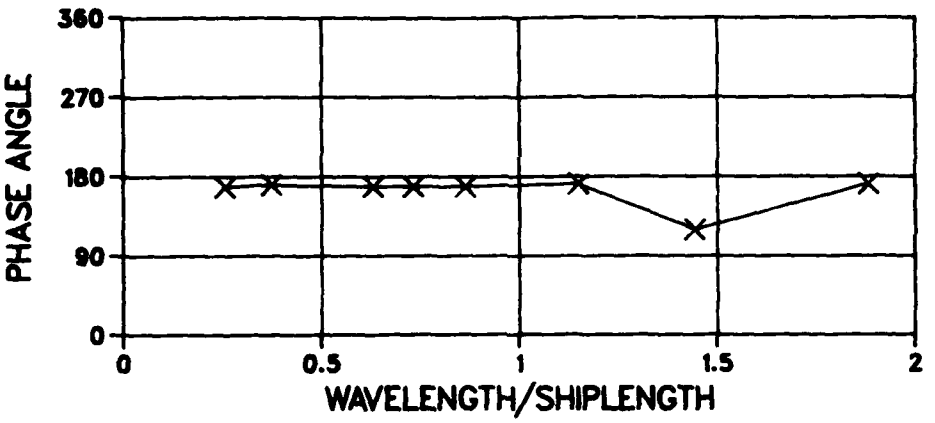
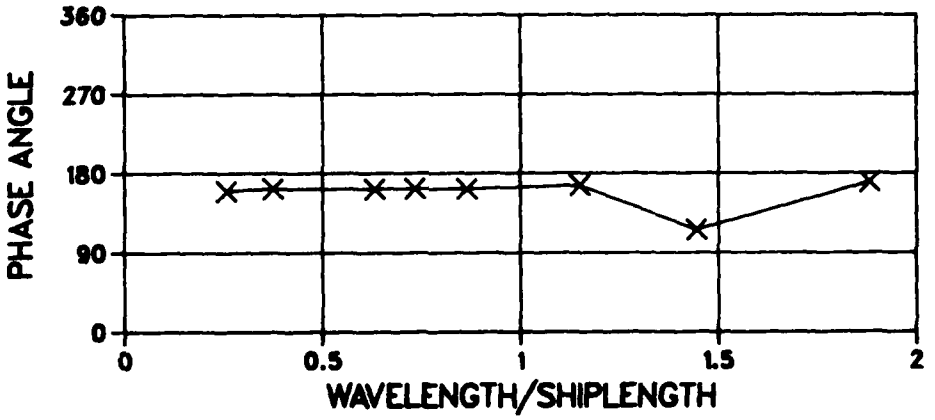


FORCED HEAVE. FN=0.1

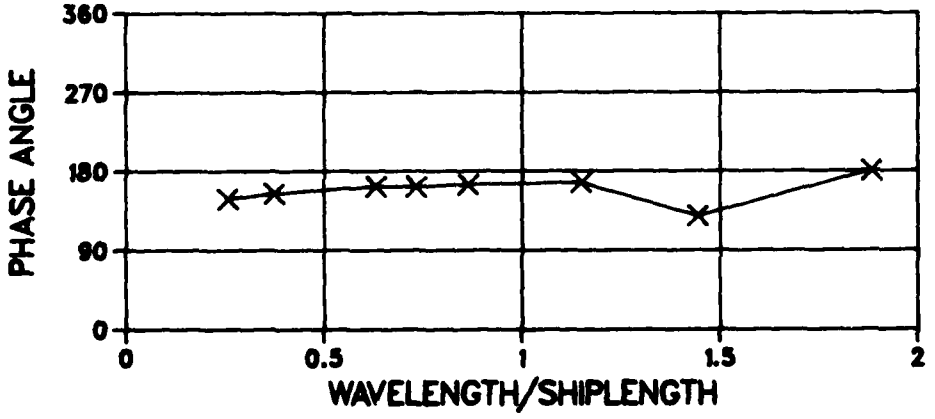
STA.20



STA.19.5



STA.19



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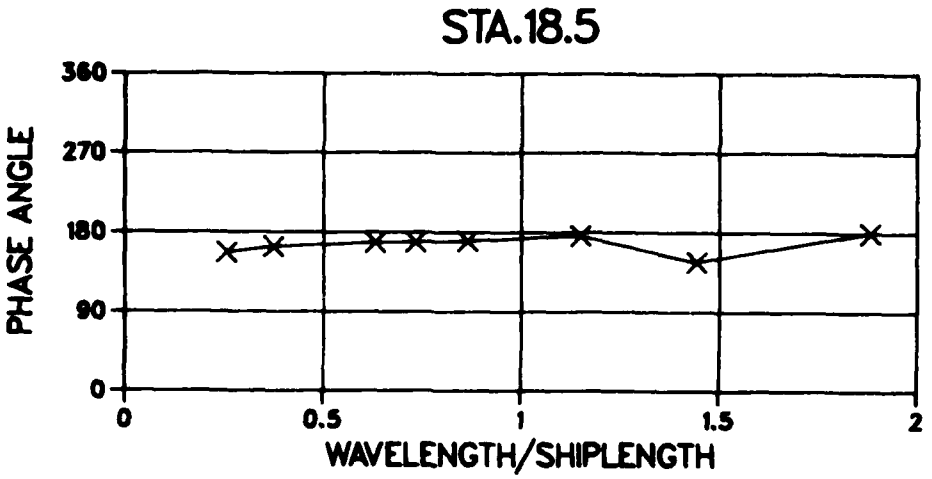
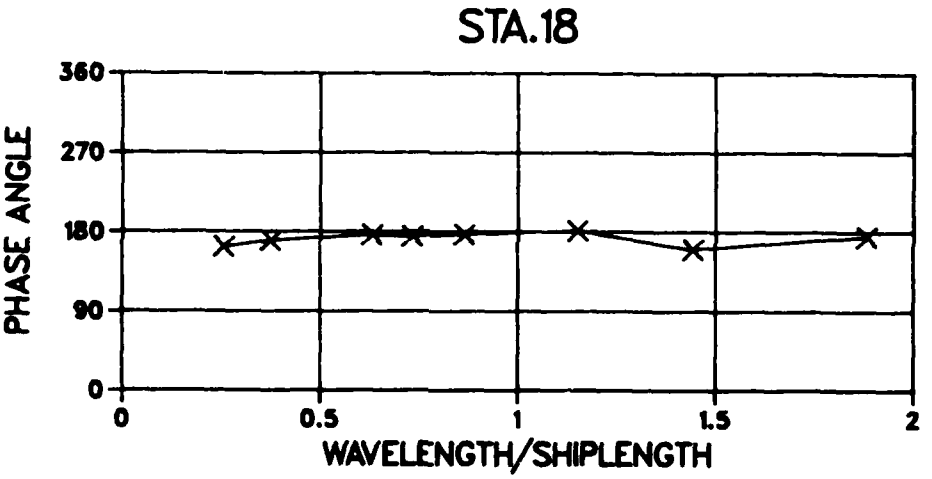
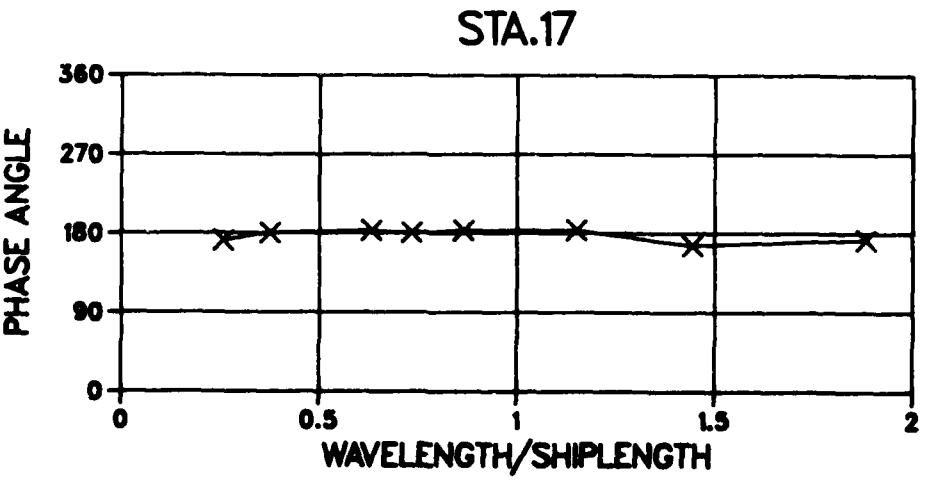
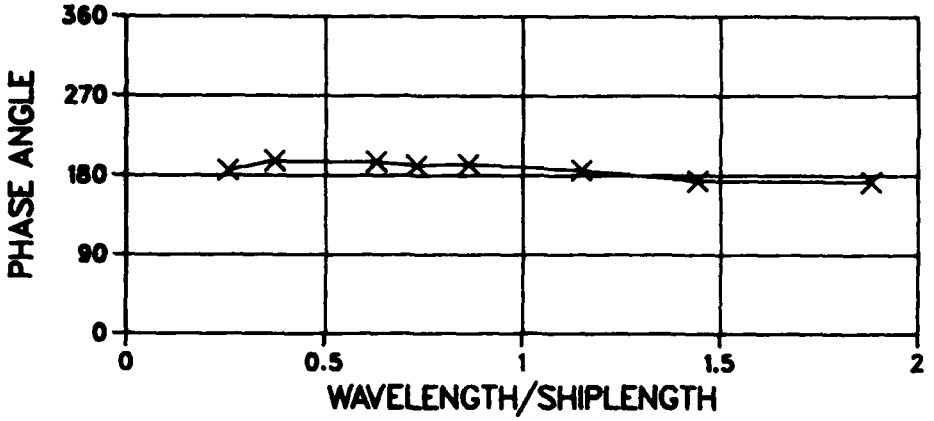




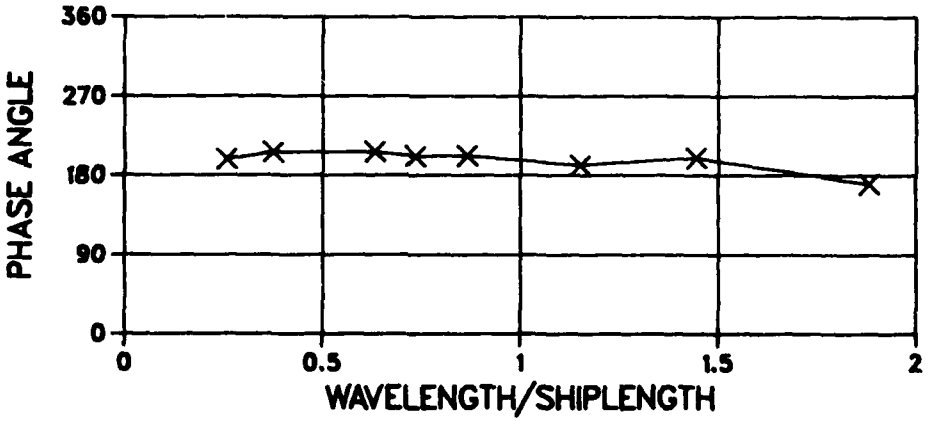


FORCED HEAVE. FN=0.1

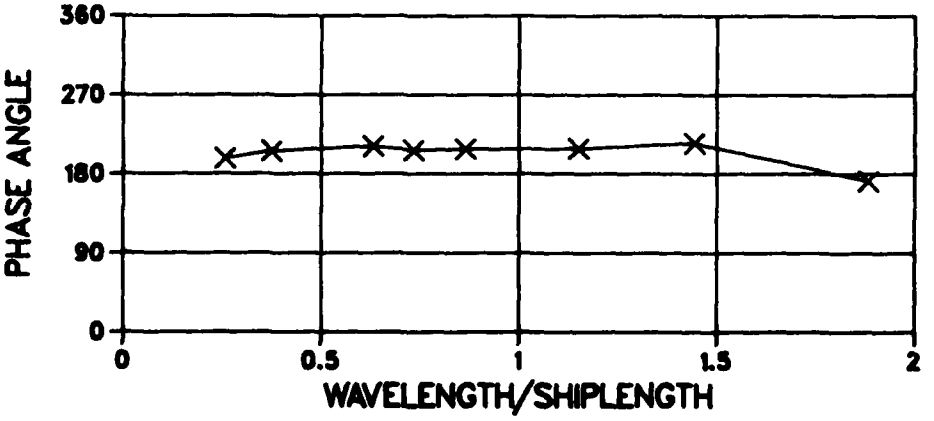
STA.16



STA.14



STA.12



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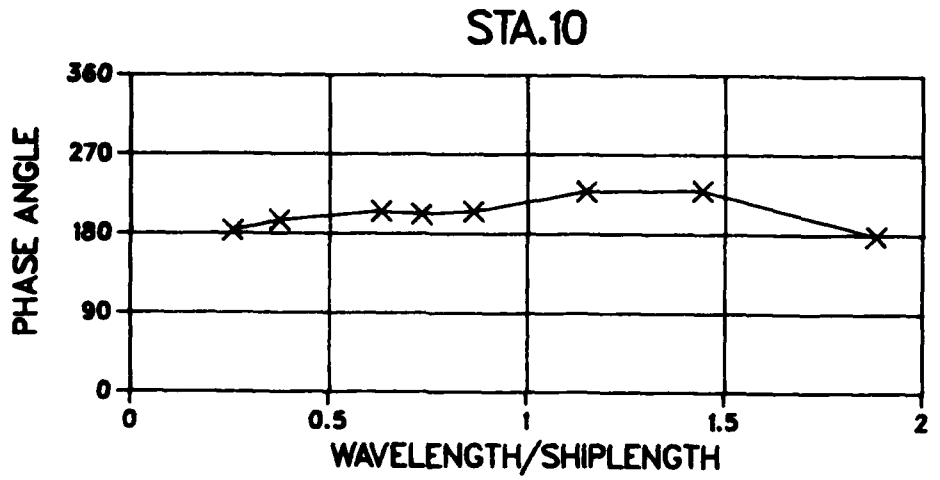
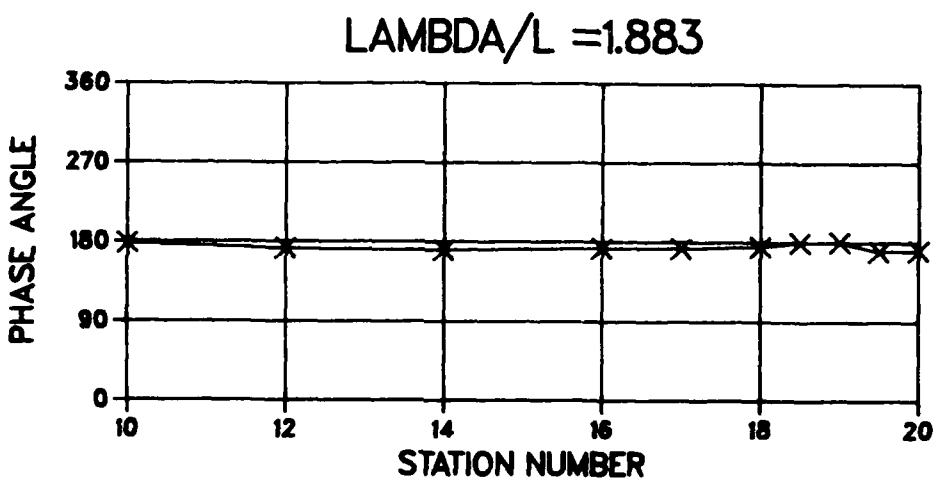
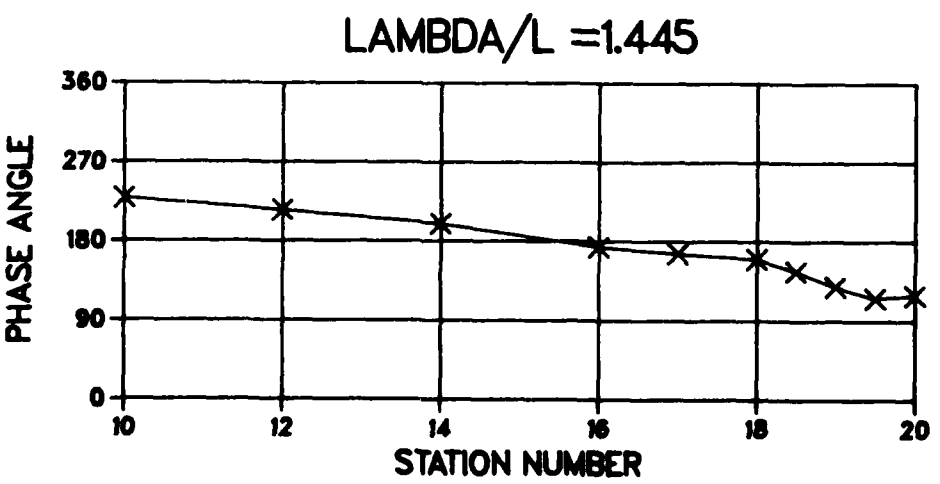
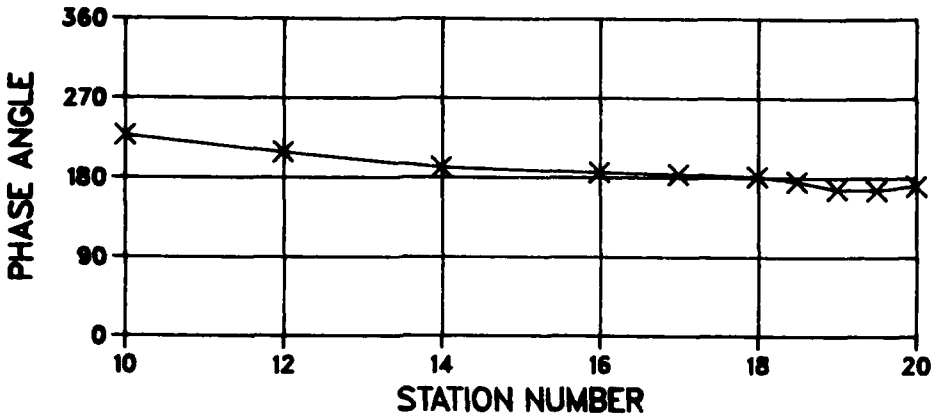




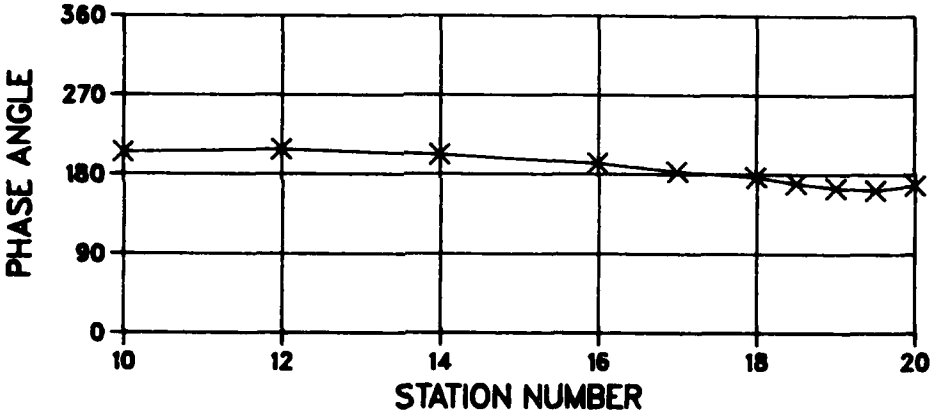


FORCED HEAVE. FN=0.1

LAMBDA/L =1.152



LAMBDA/L =0.865



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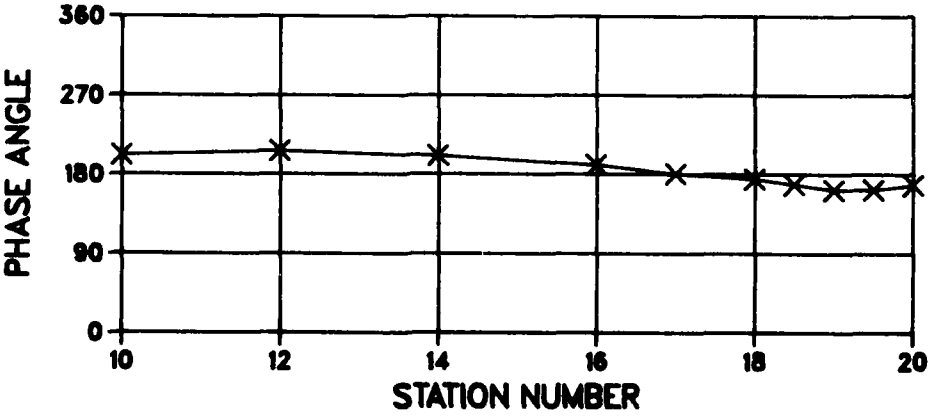
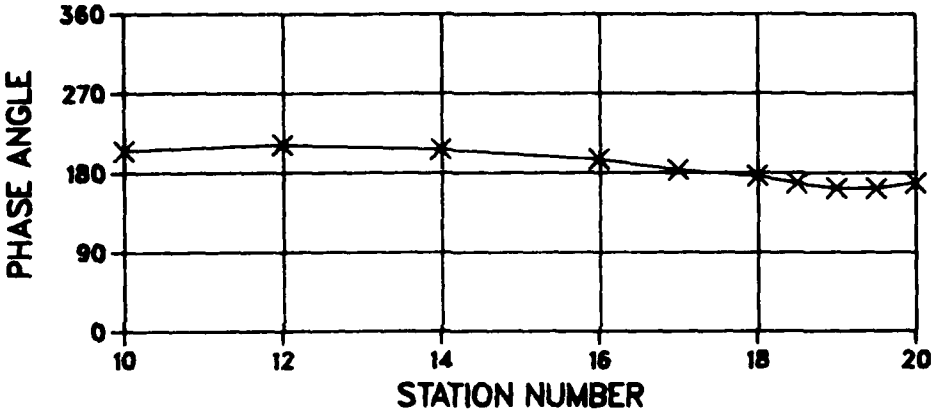


FORCED HEAVE. FN=0.1

LAMBDA/L =0.634



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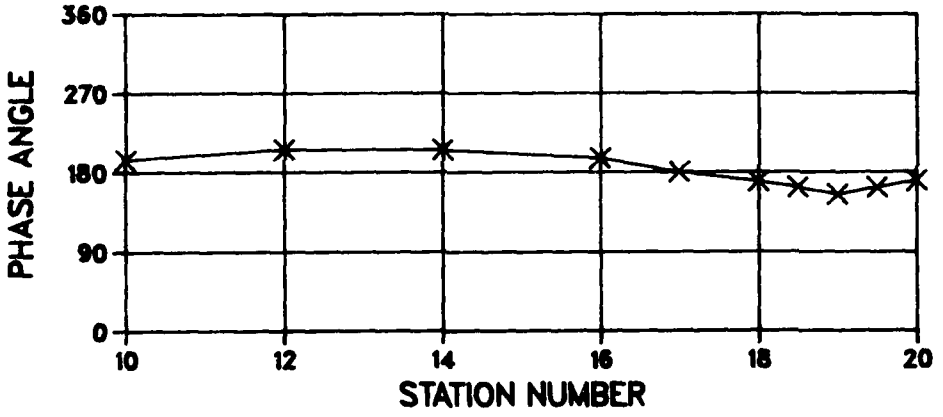
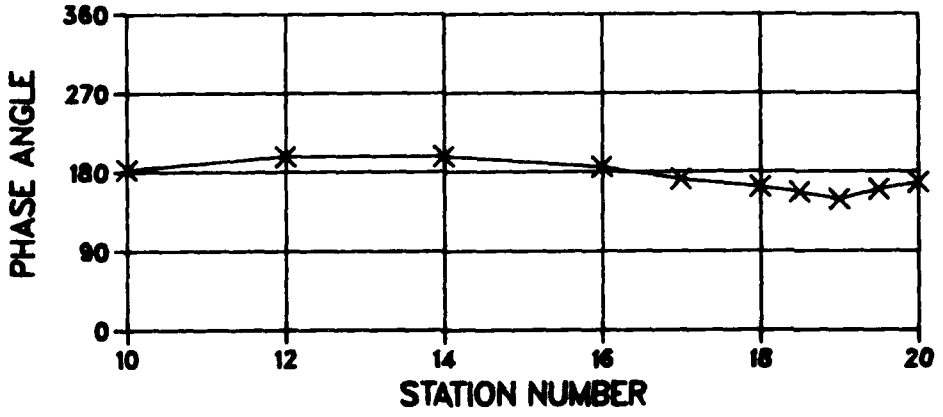
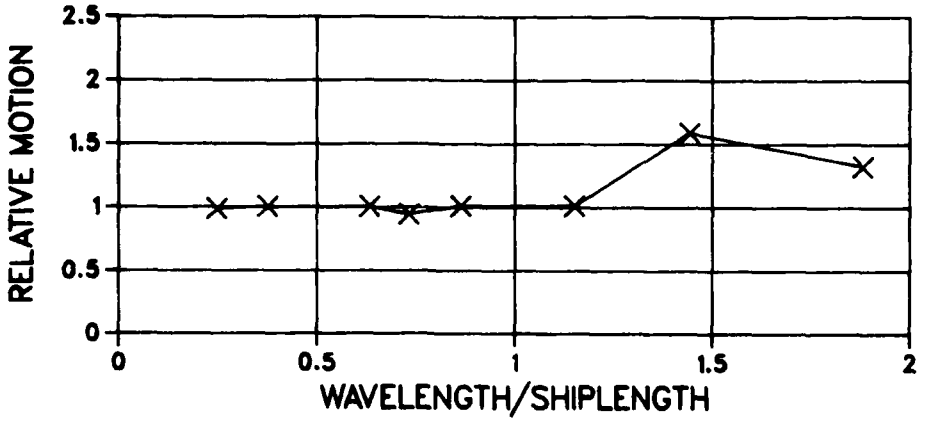


LAMBDA/L =0.257



FORCED PITCH. FN=0.1

STA.20



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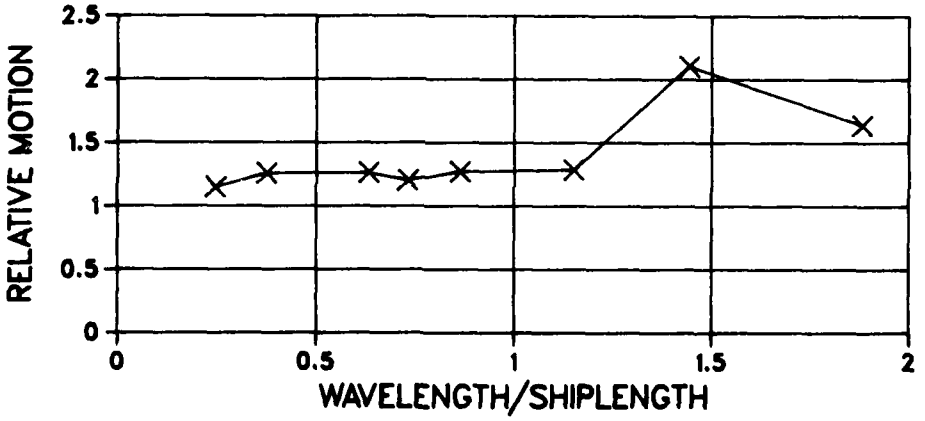
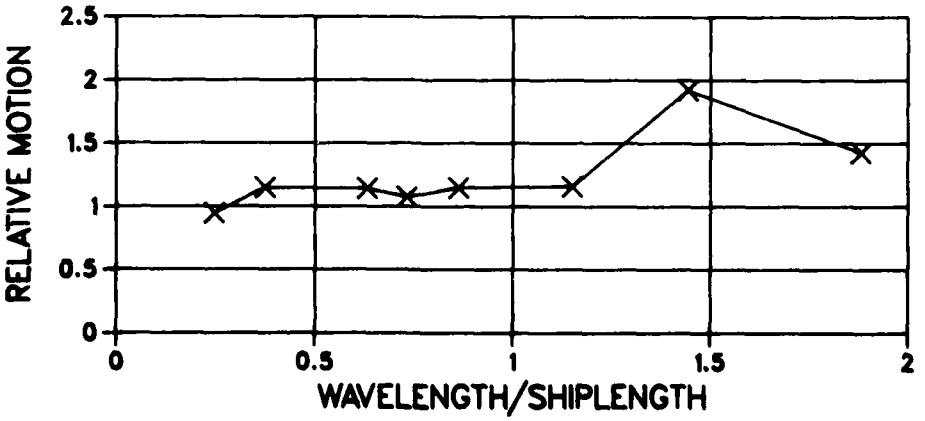
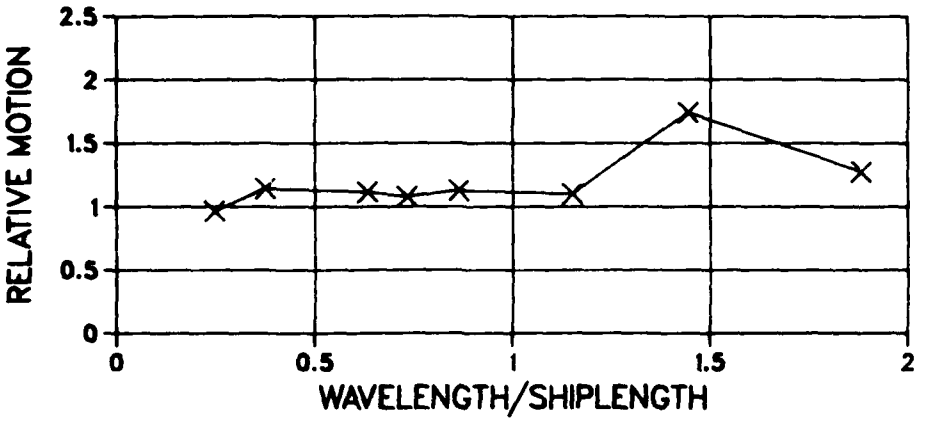


STA.19

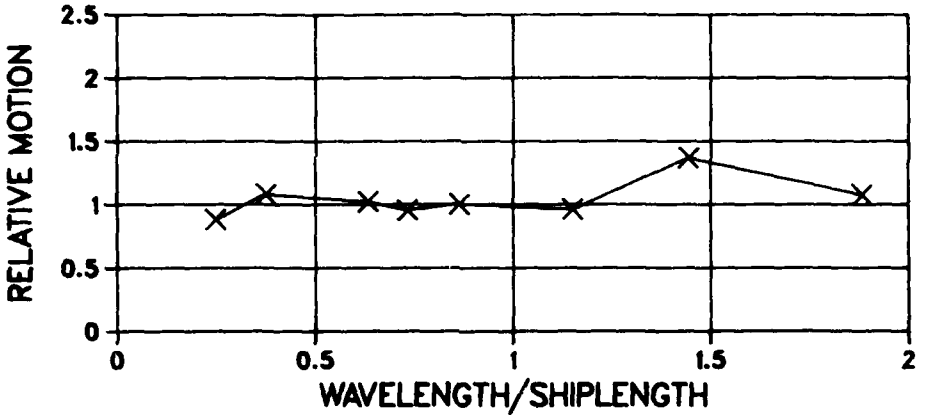


FORCED PITCH. FN=0.1

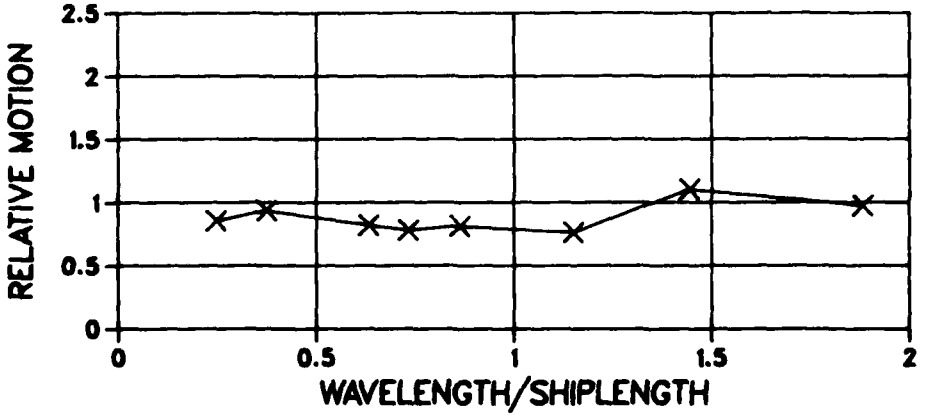
STA.18.5



STA.18

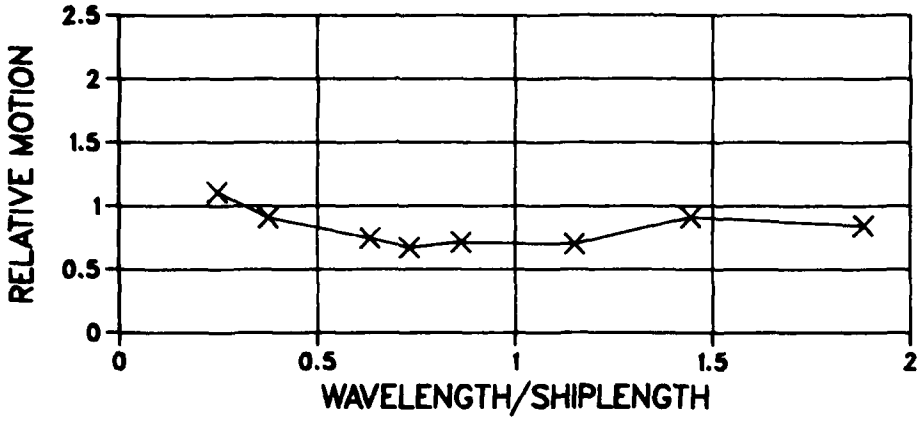


STA.17

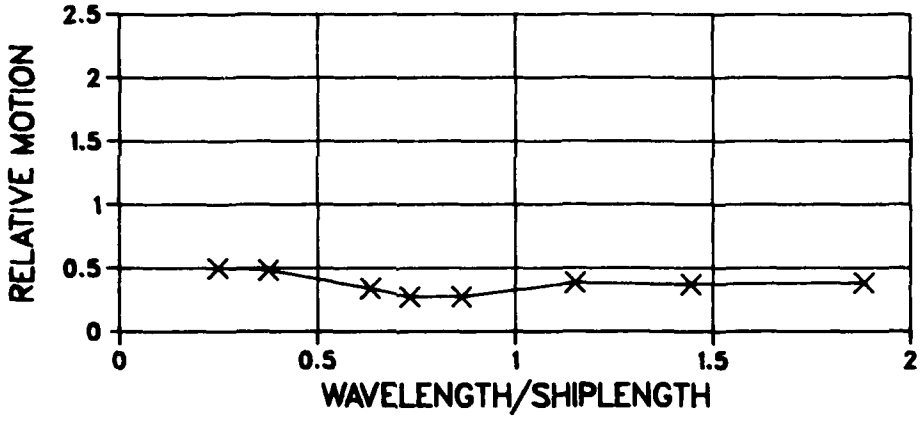


FORCED PITCH. FN=0.1

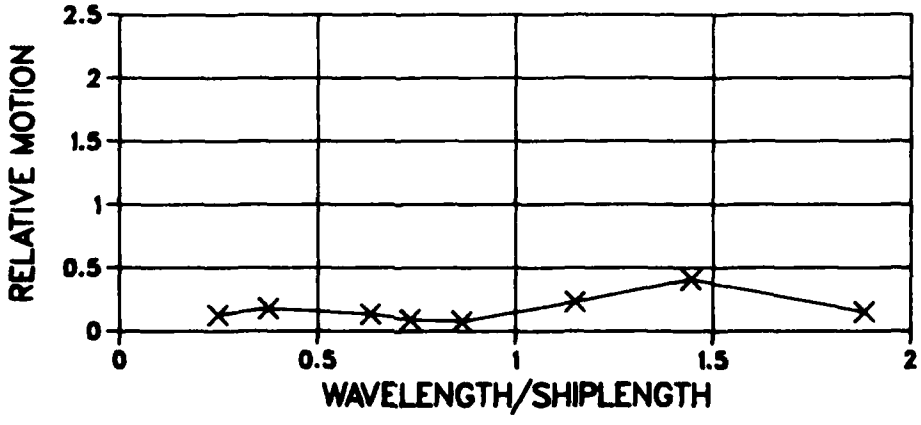
STA.16



STA.14

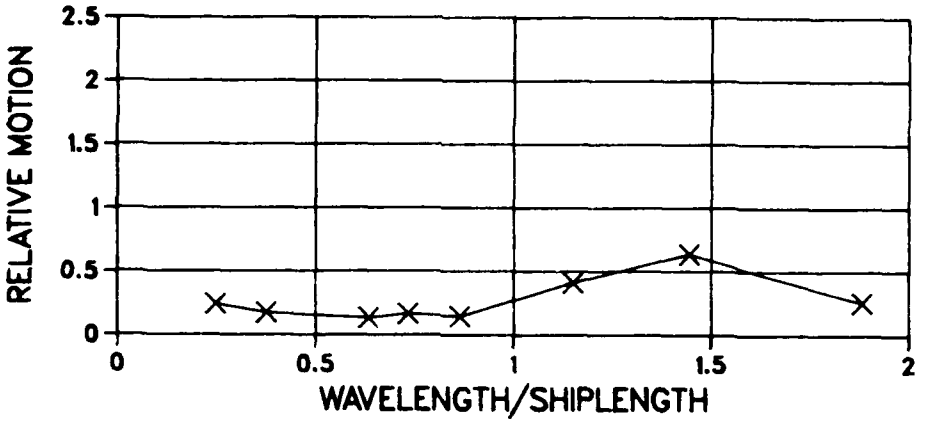


STA.12



FORCED PITCH. FN=0.1

STA.10



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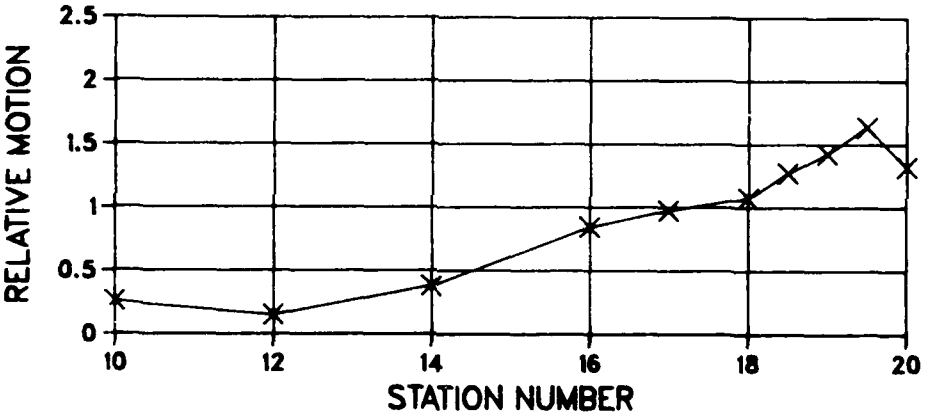

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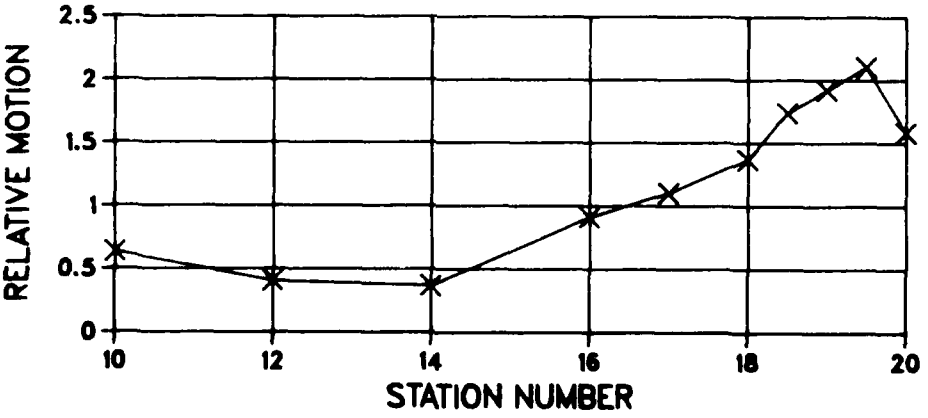
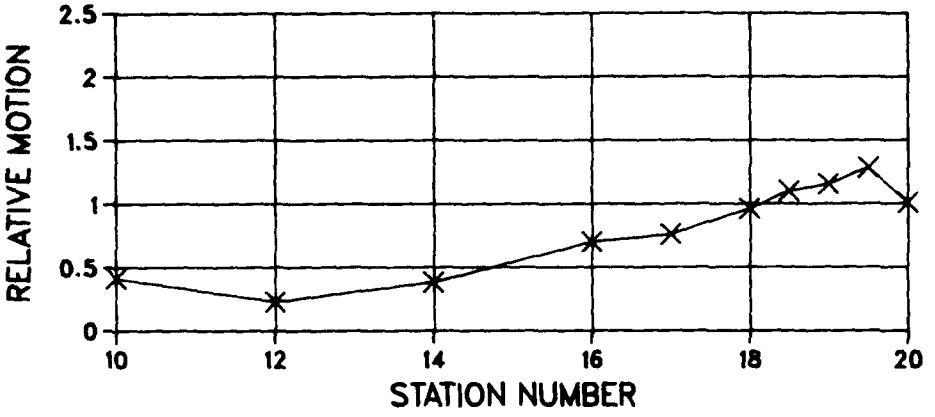
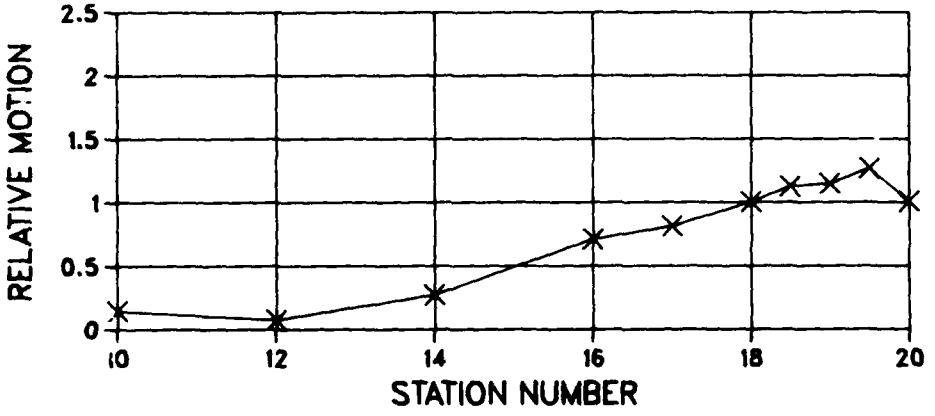


FORCED PITCH. FN=0.1

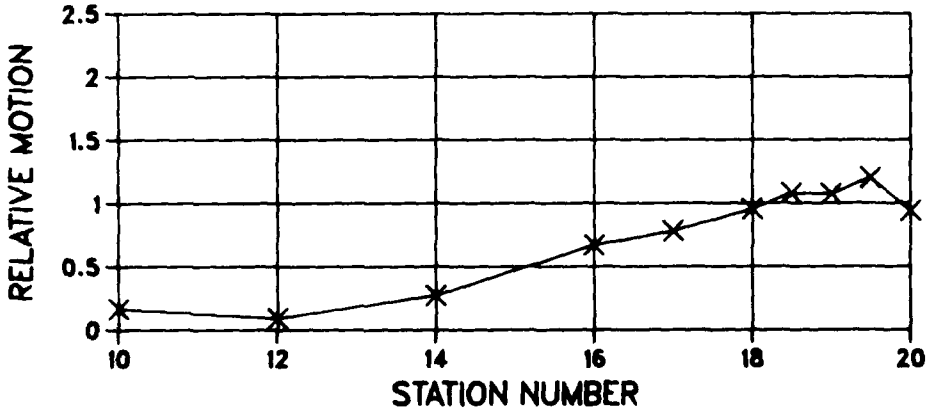
LAMBDA/L =1.152



LAMBDA/L =0.865

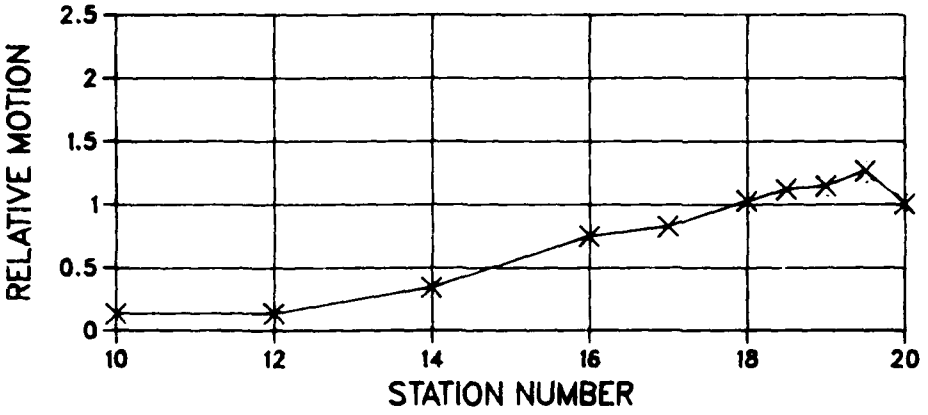


LAMBDA/L =0.734



FORCED PITCH. FN=0.1

LAMBDA/L =0.634



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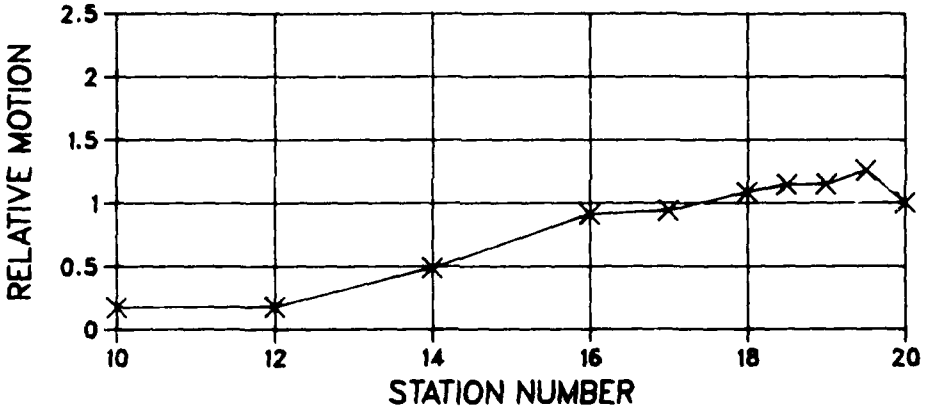

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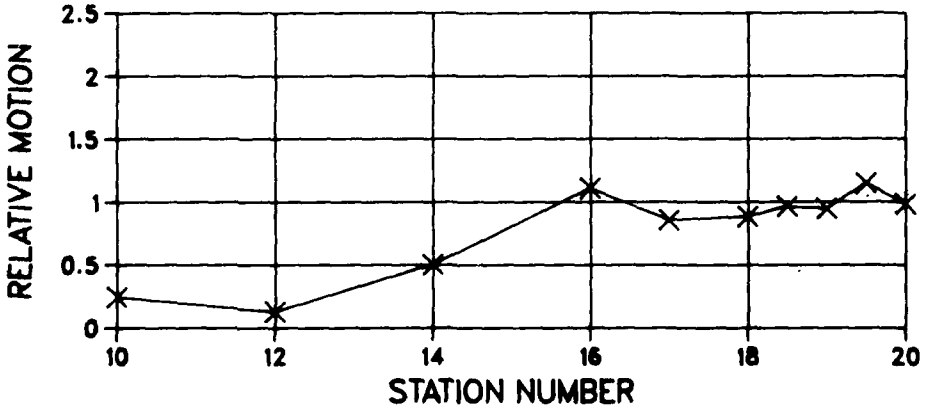
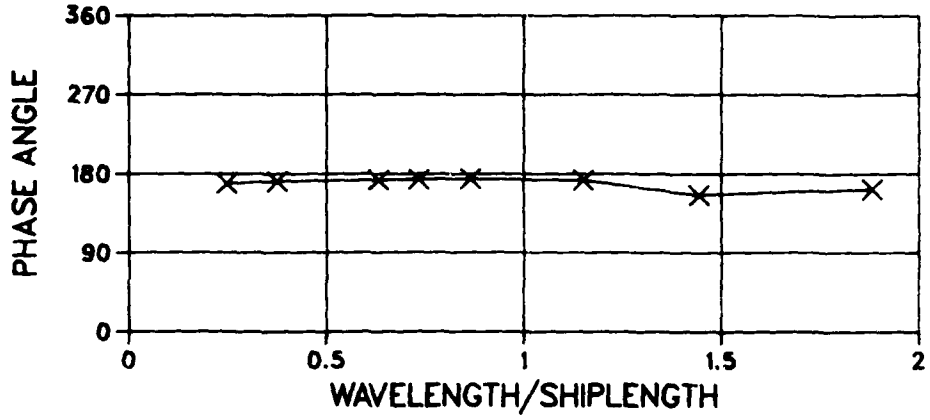


FORCED PITCH. FN=0.1

STA.20



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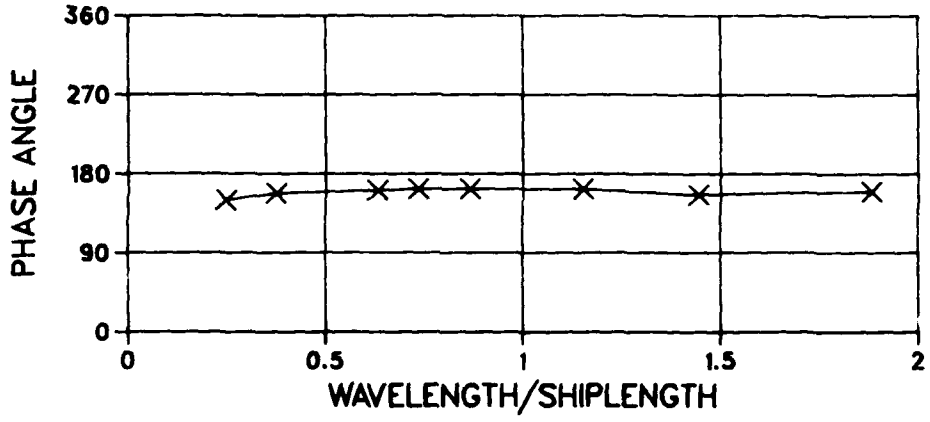
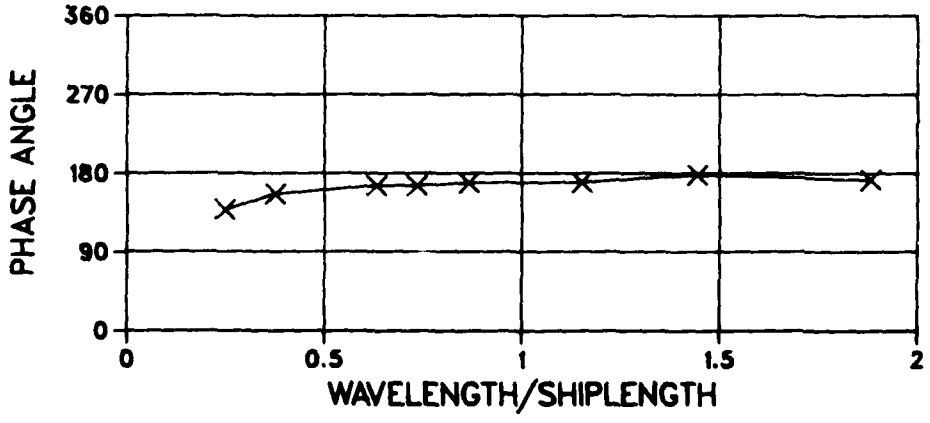
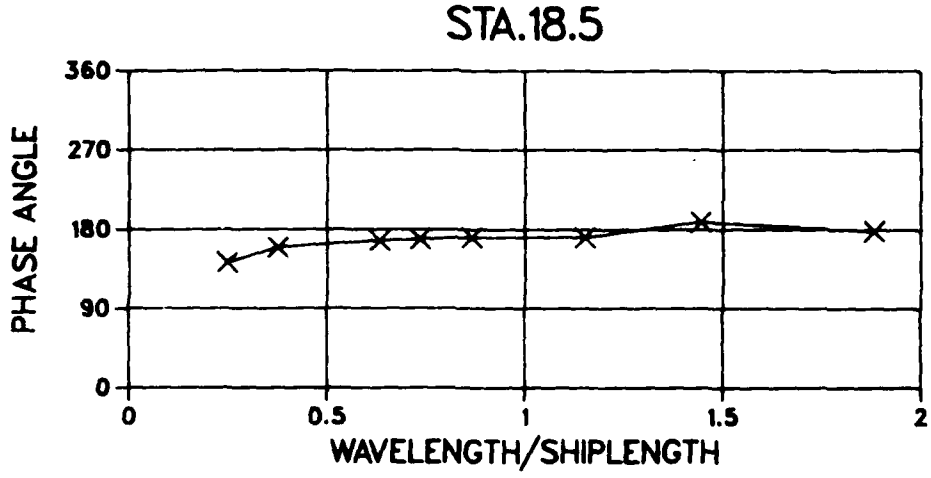
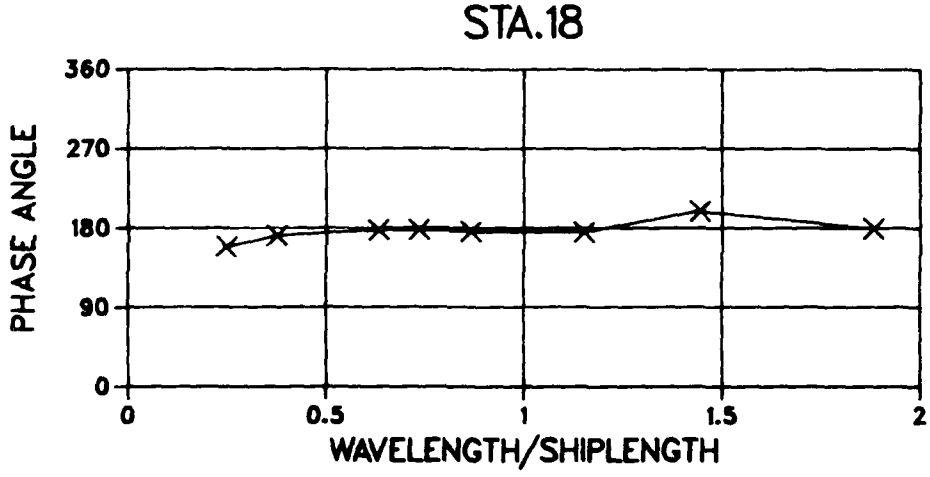


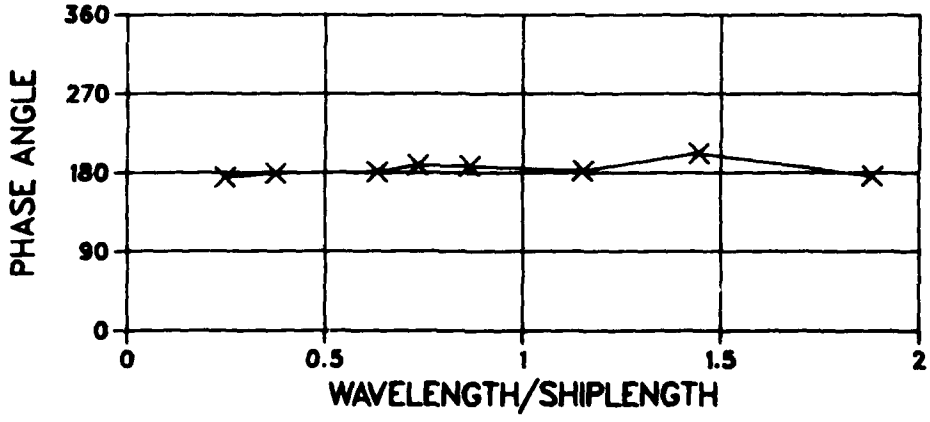
STA.19



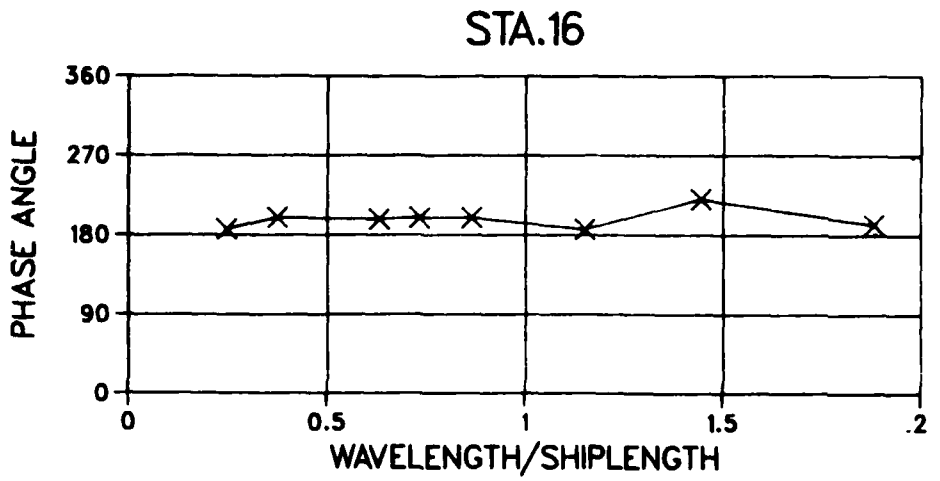
FORCED PITCH. FN=0.1

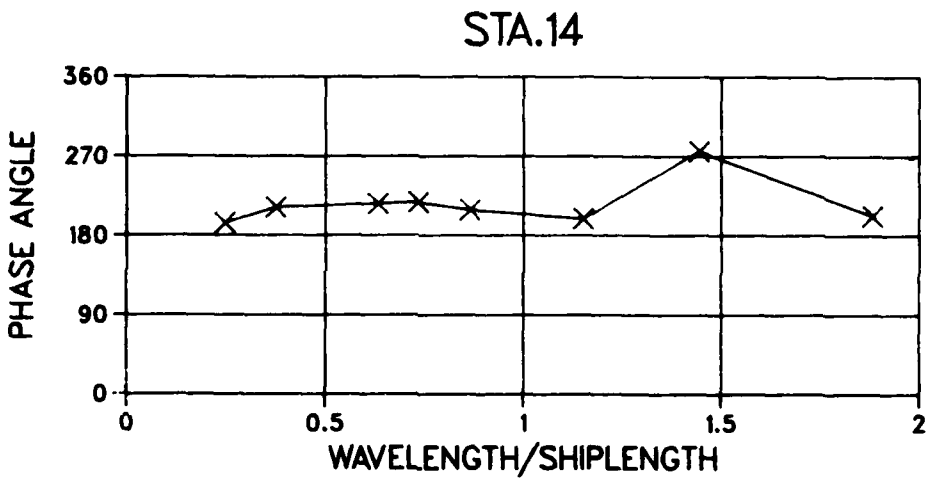


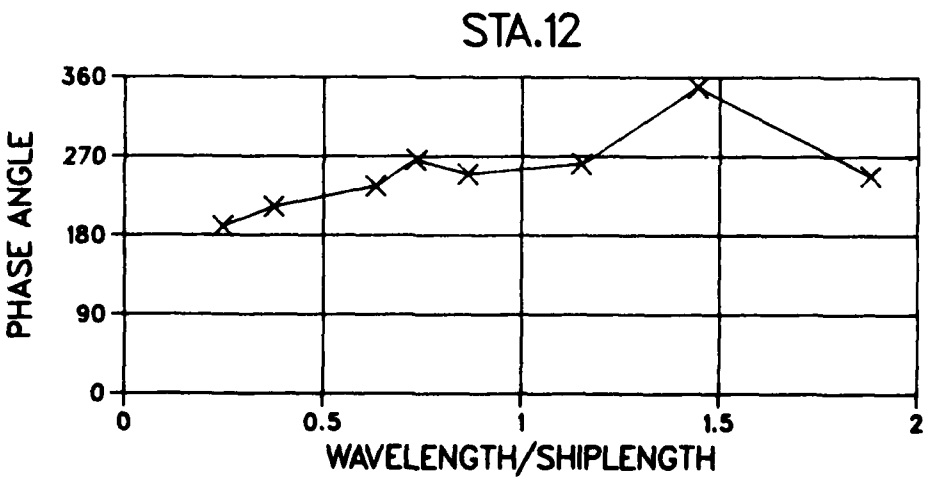




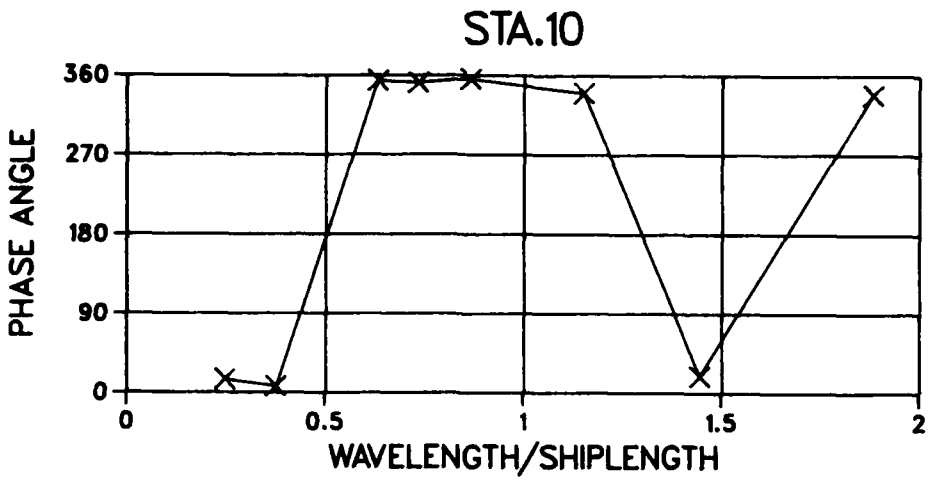
FORCED PITCH. FN=0.1

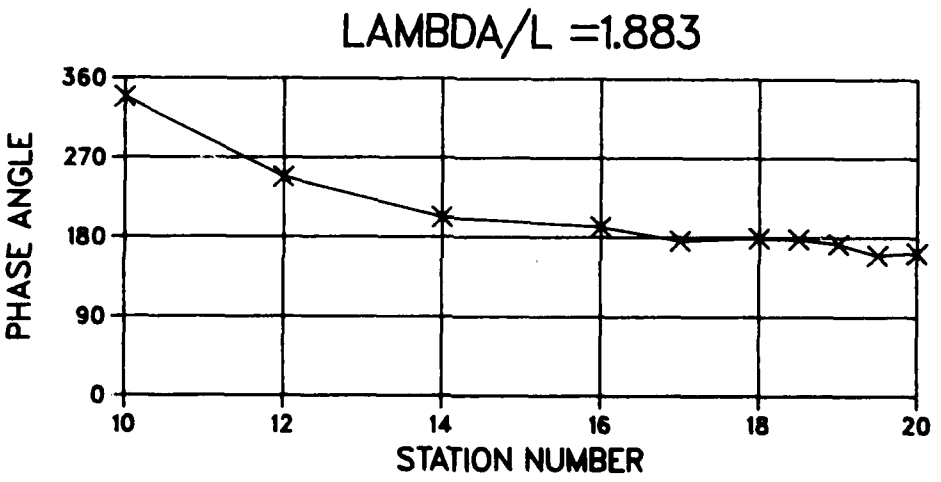


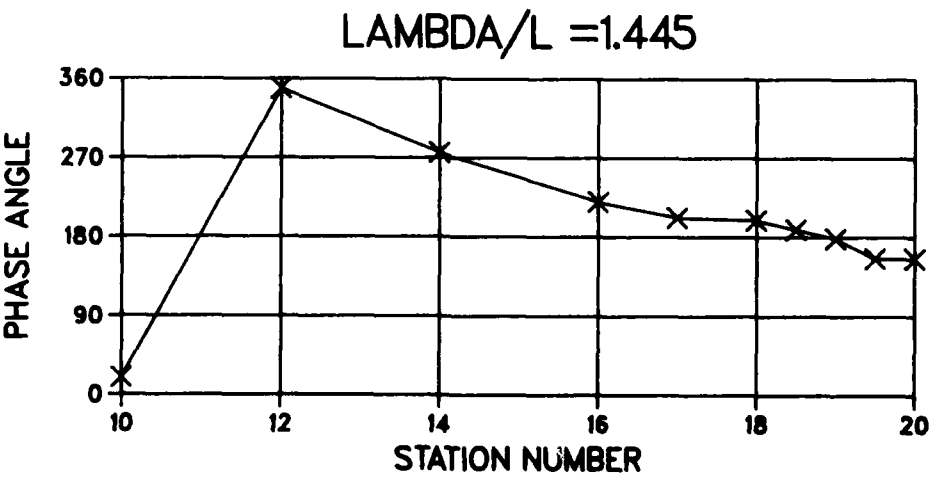




FORCED PITCH. FN=0.1

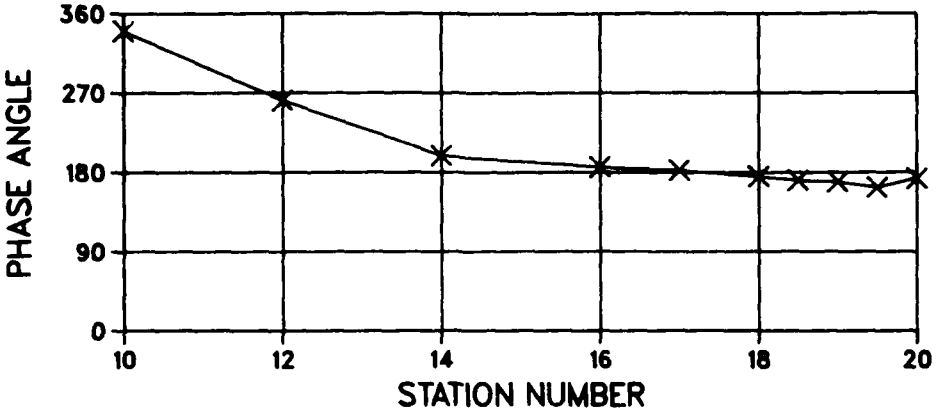




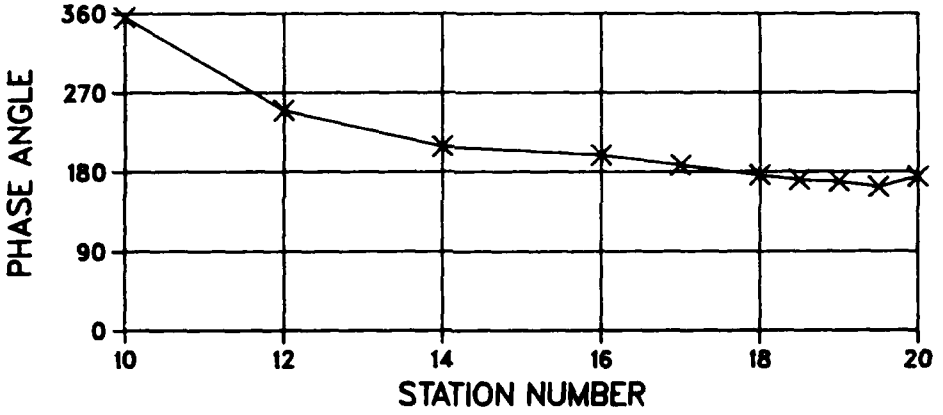


FORCED PITCH. FN=0.1

LAMBDA/L =1.152



LAMBDA/L =0.865



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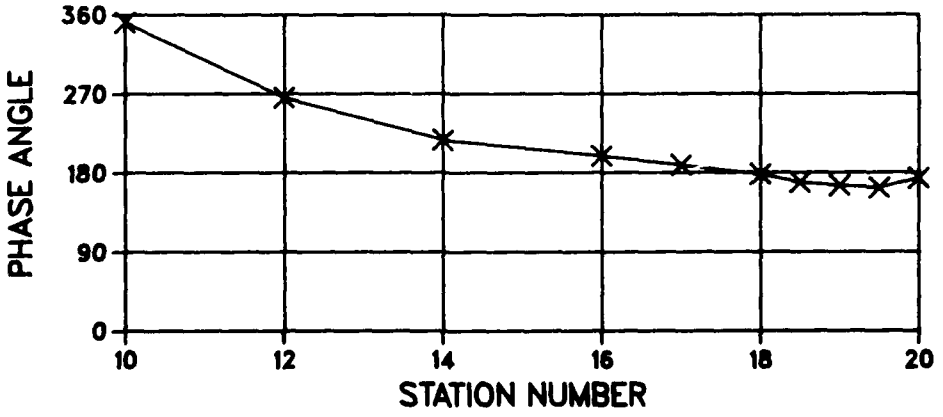

FORCED PITCH. FN=0.1

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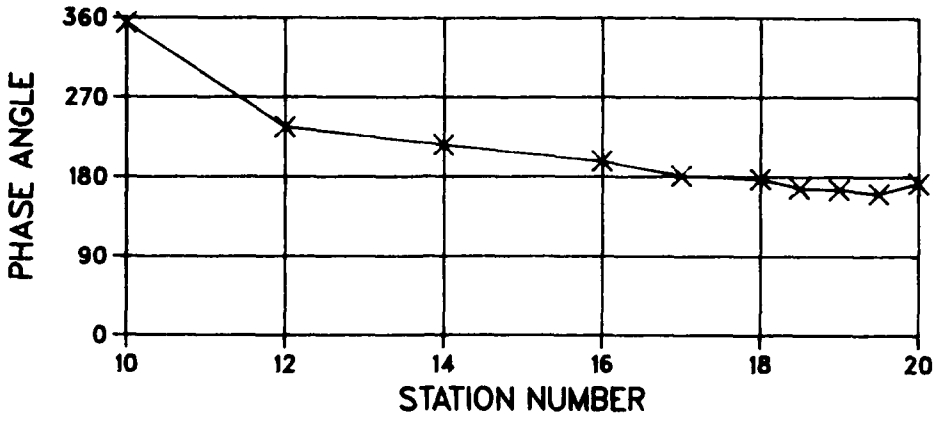

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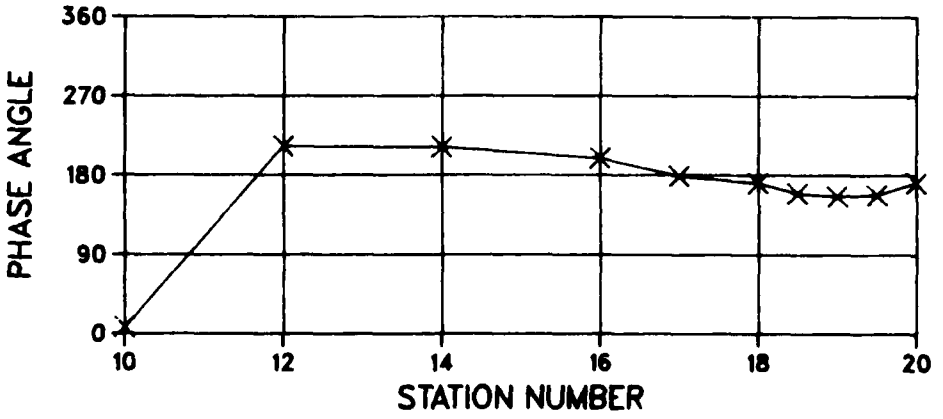
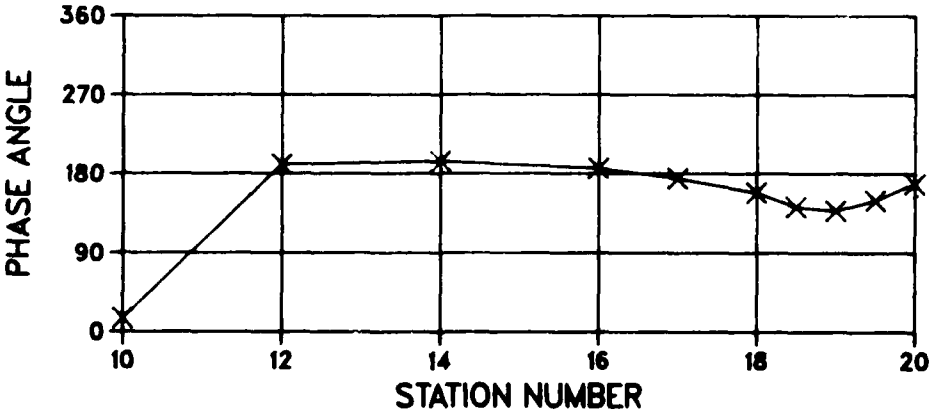
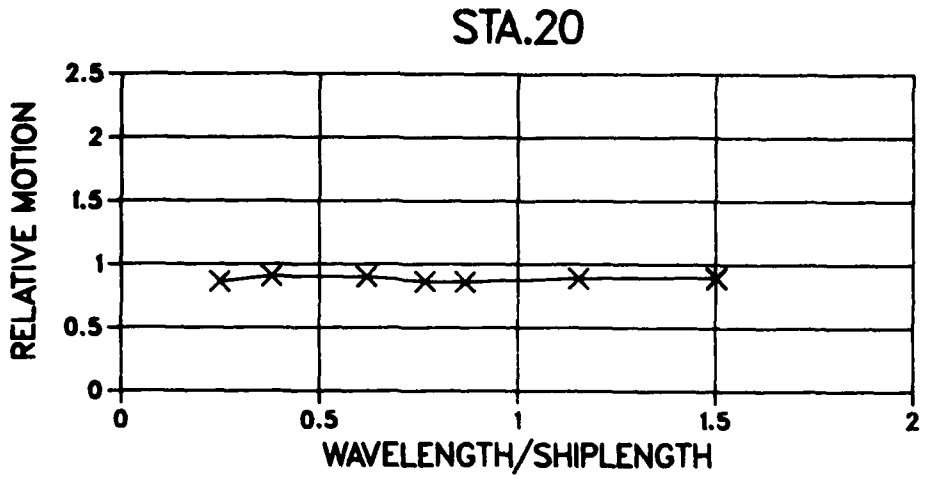
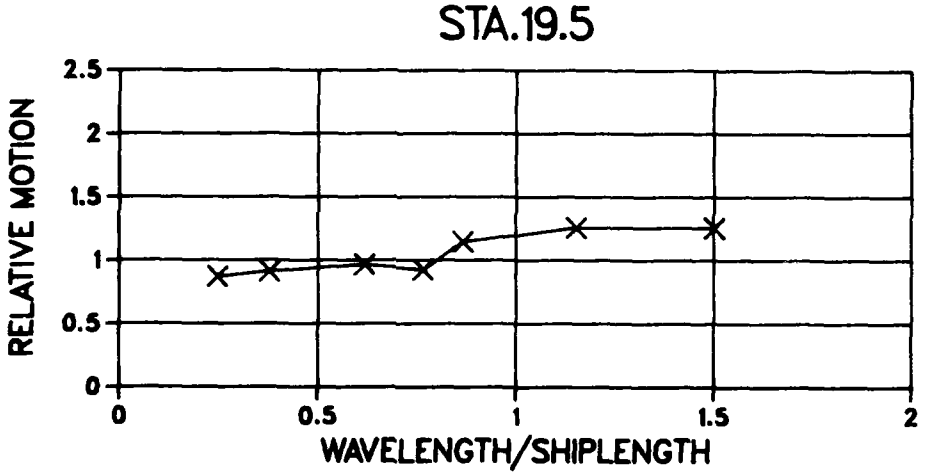


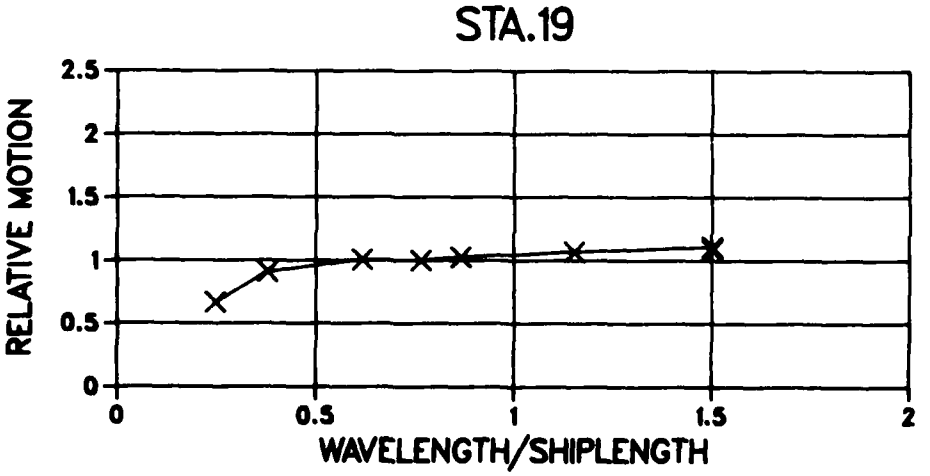
LAMBDA/L =0.248



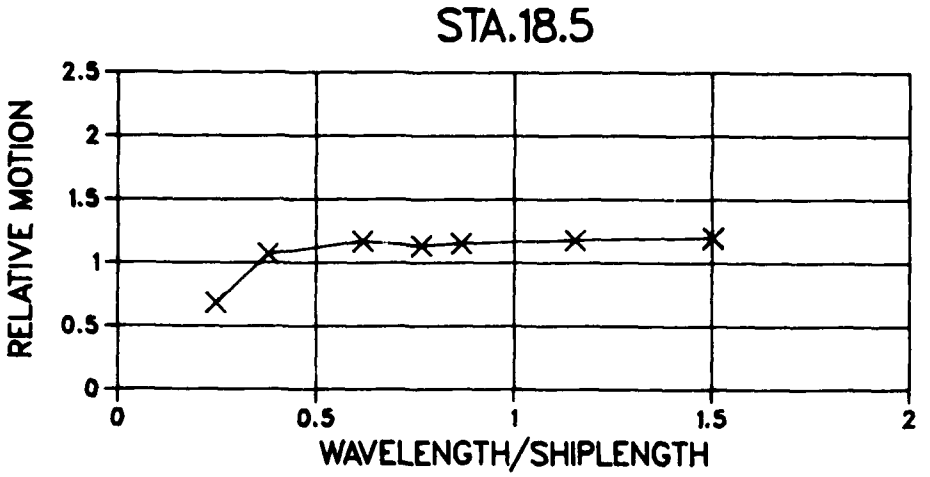
FORCED HEAVE. FN=0.2

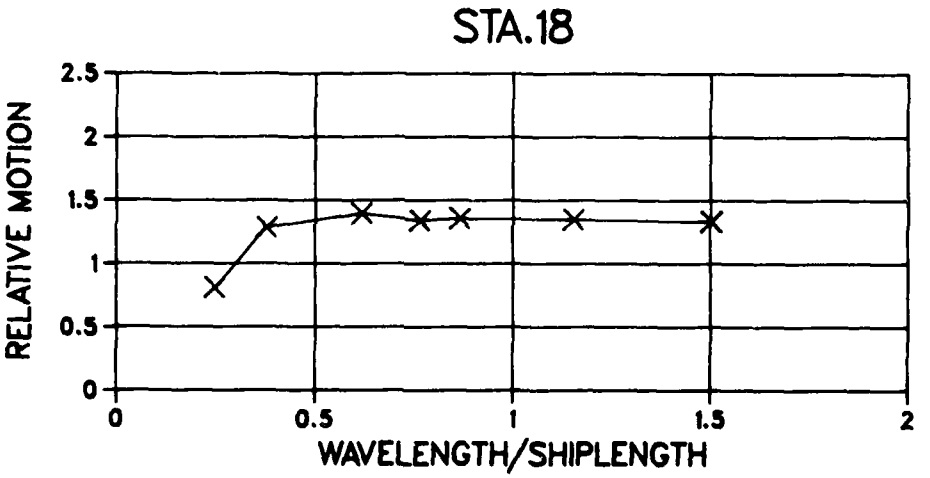


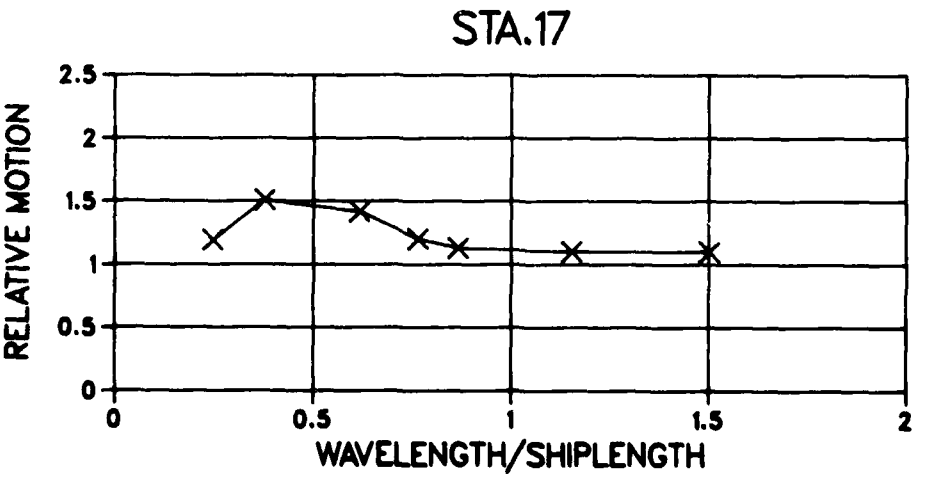




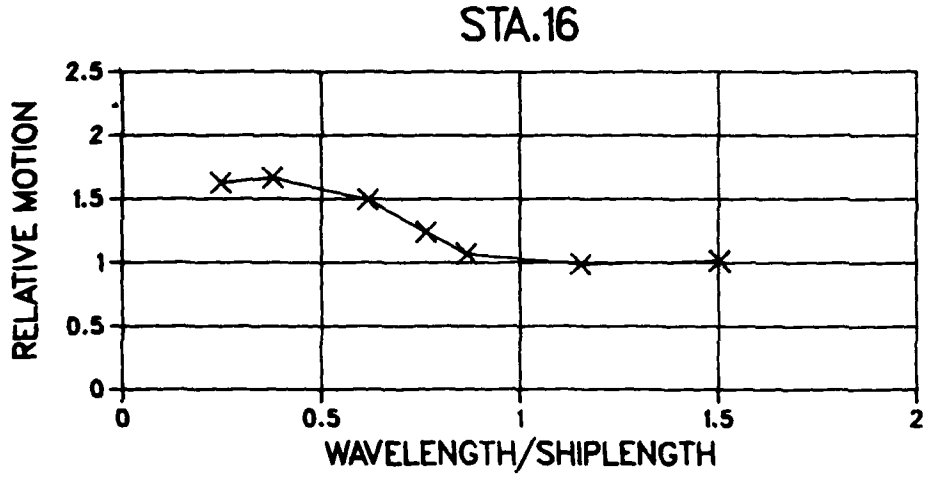
FORCED HEAVE. FN=0.2

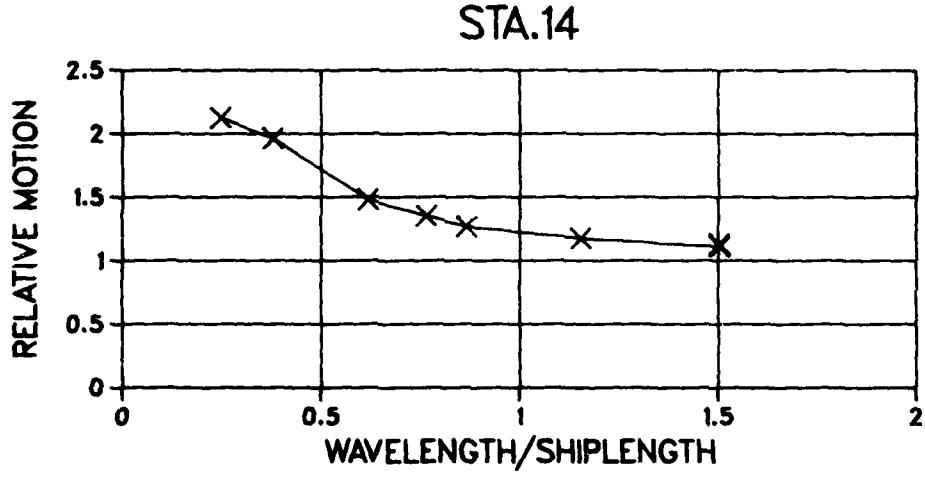


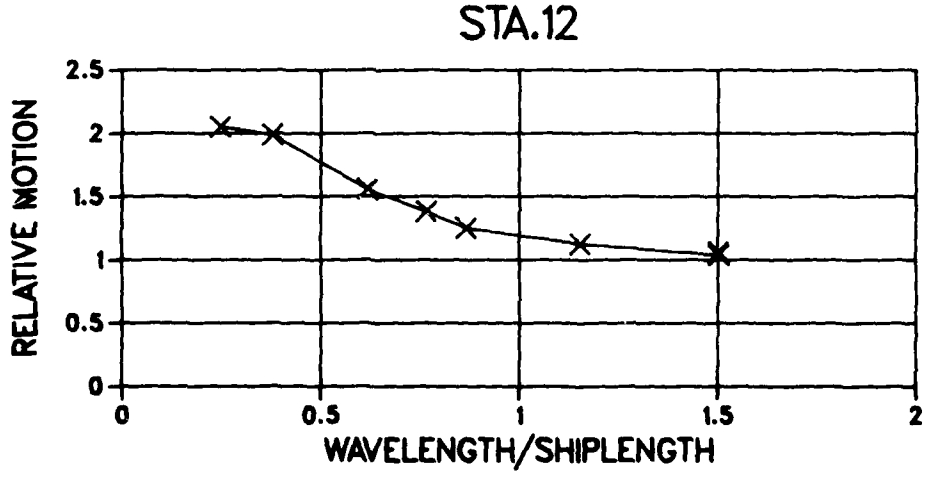




FORCED HEAVE. FN=0.2

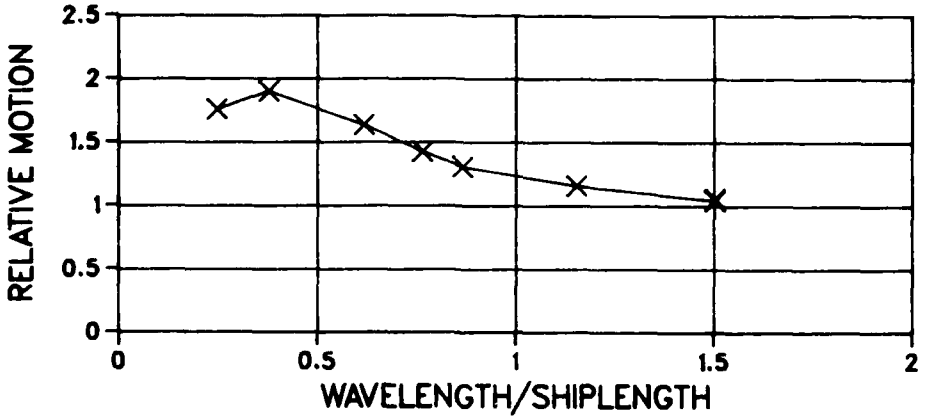




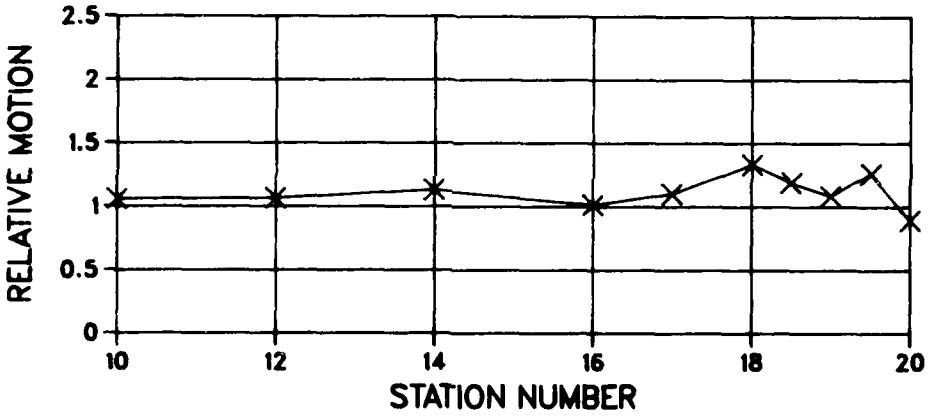


FORCED HEAVE. FN=0.2

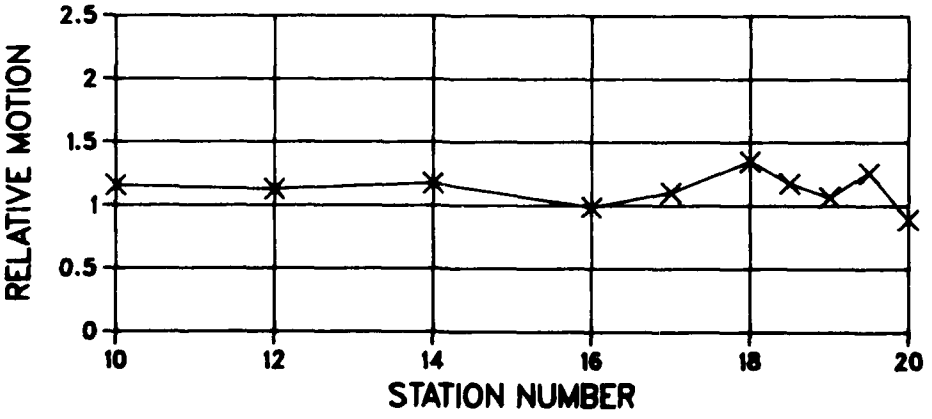
STA.10



LAMBDA/L =1.503



LAMBDA/L =1.154



FORCED HEAVE. FN=0.2

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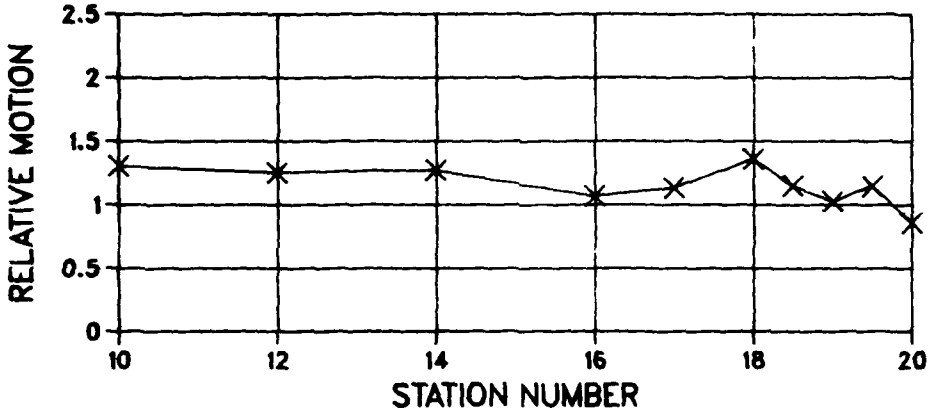

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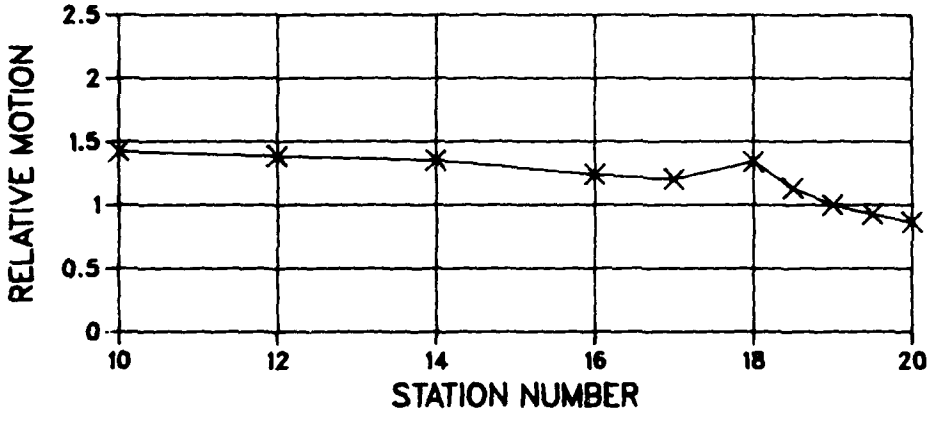

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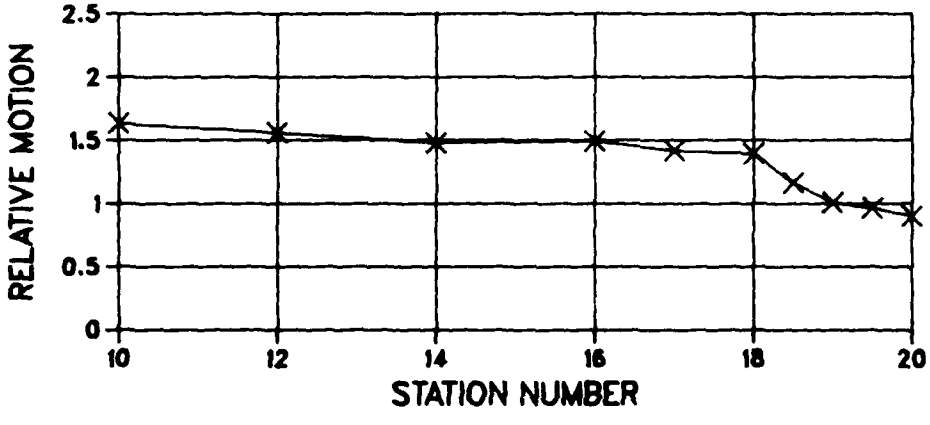
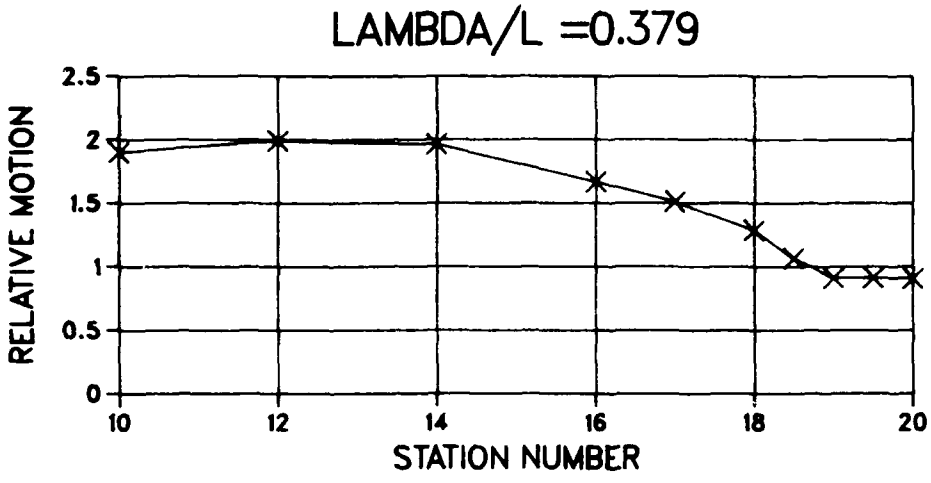
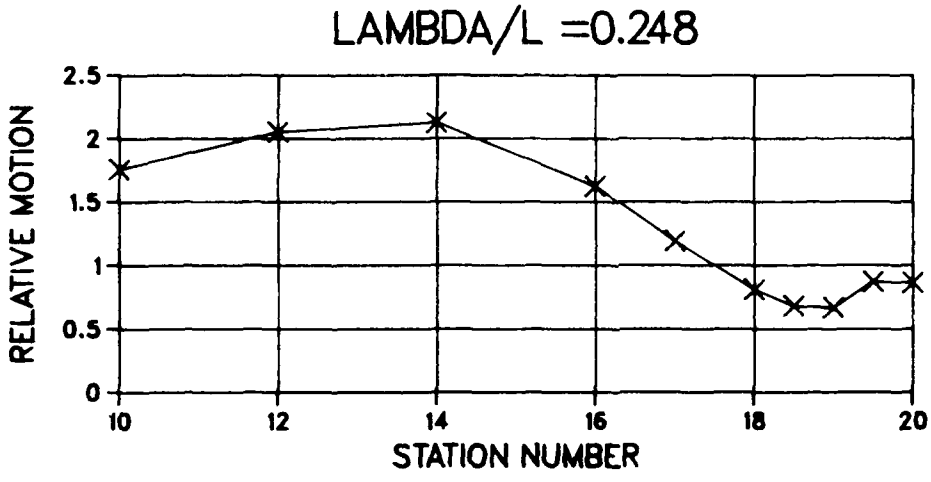


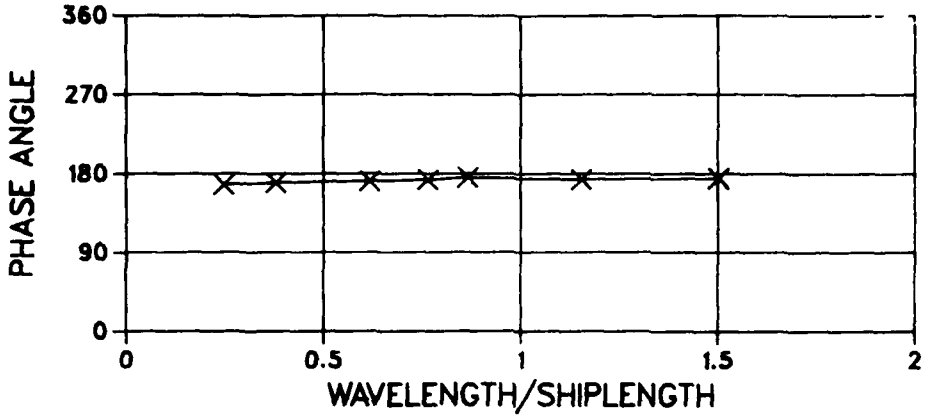
FORCED HEAVE. FN=0.2



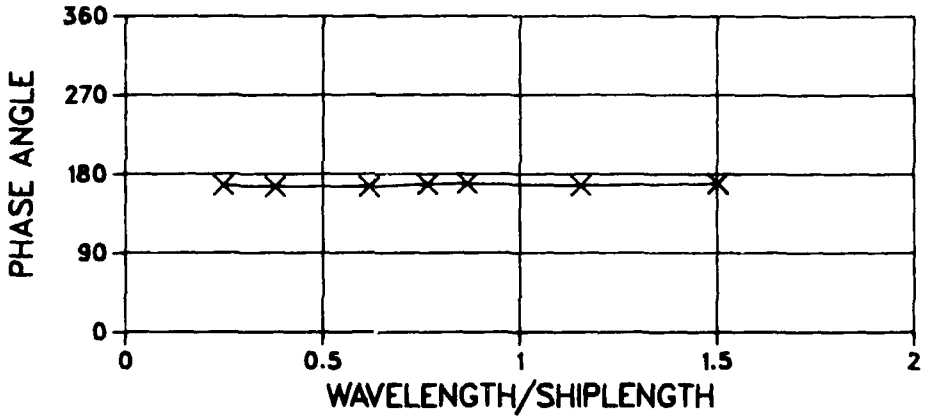


FORCED HEAVE. FN=0.2

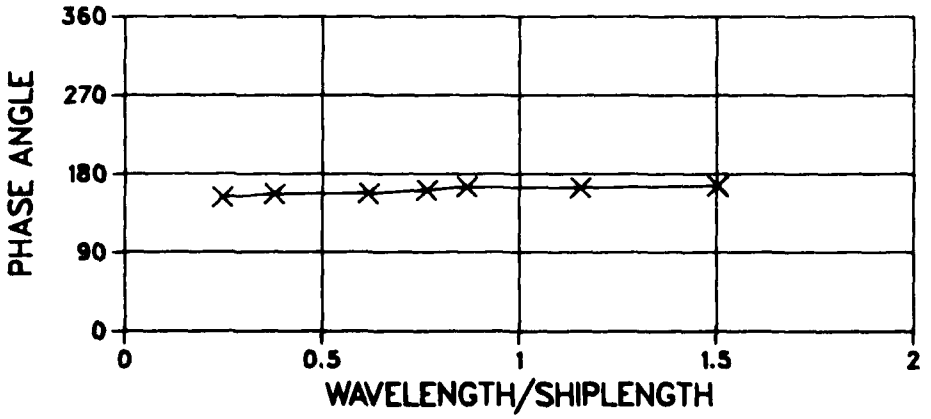
STA.20



STA.19.5

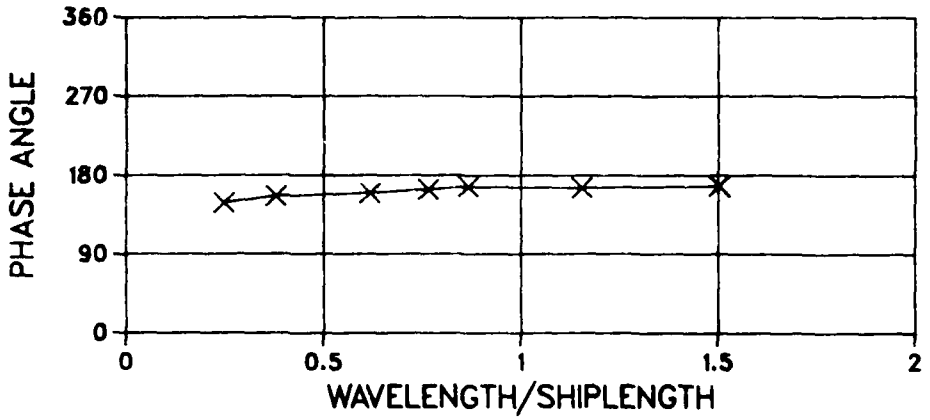


STA.19

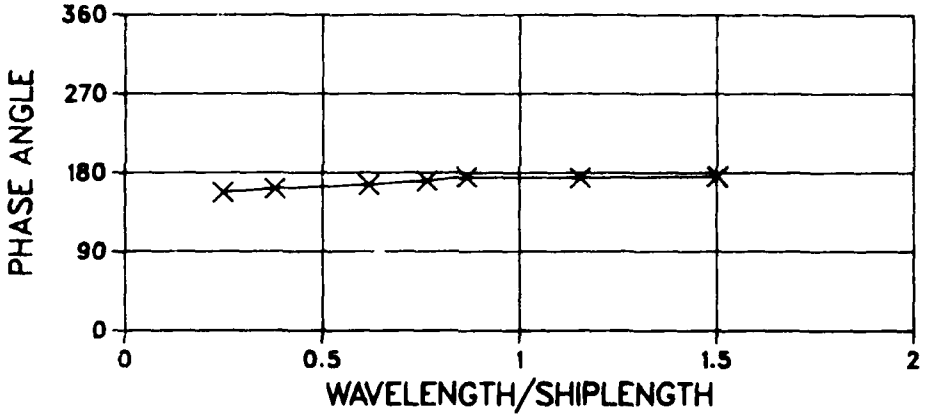


FORCED HEAVE. FN=0.2

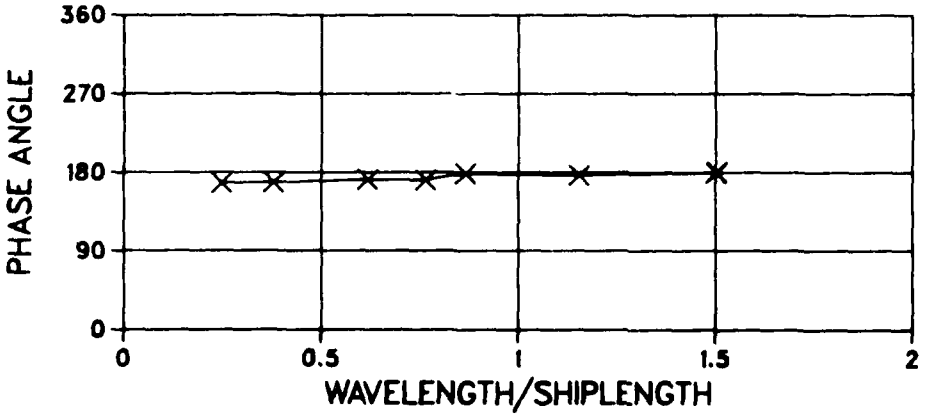
STA.18.5



STA.18

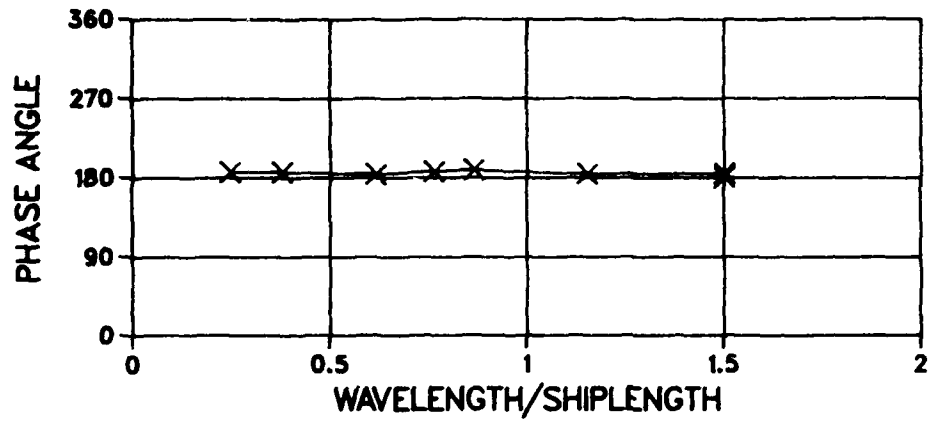


STA.17

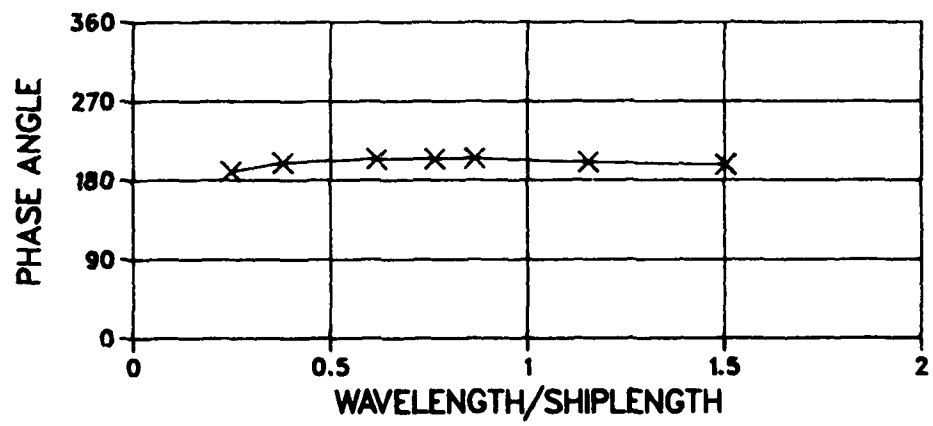


FORCED HEAVE. FN=0.2

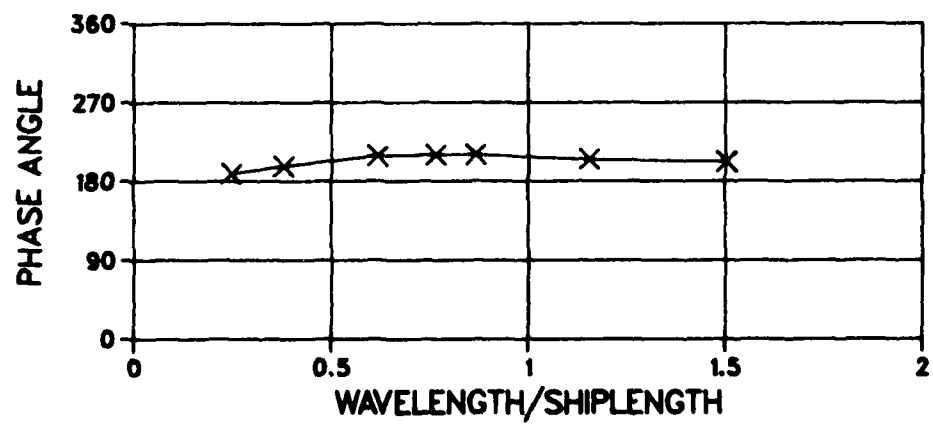
STA.16



STA.14

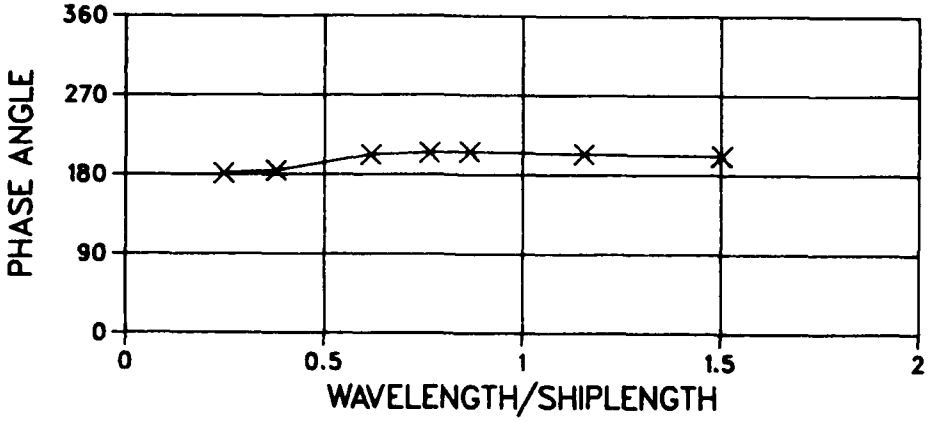


STA.12

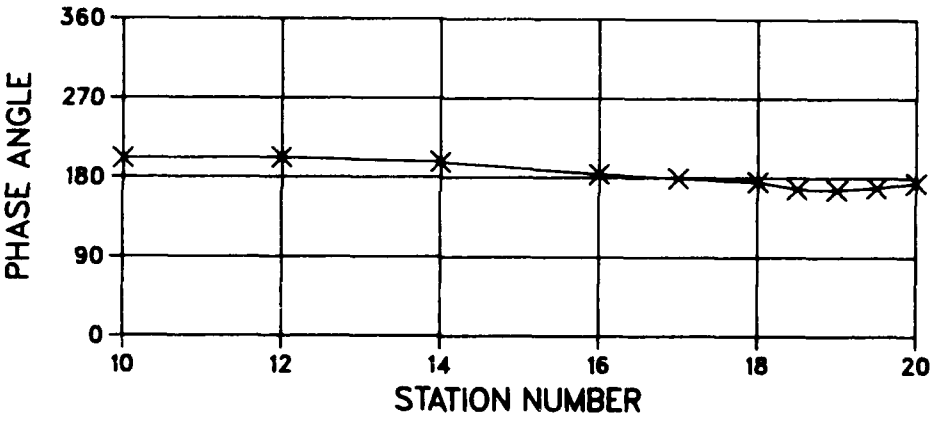


FORCED HEAVE. FN=0.2

STA.10



LAMBDA/L =1.503



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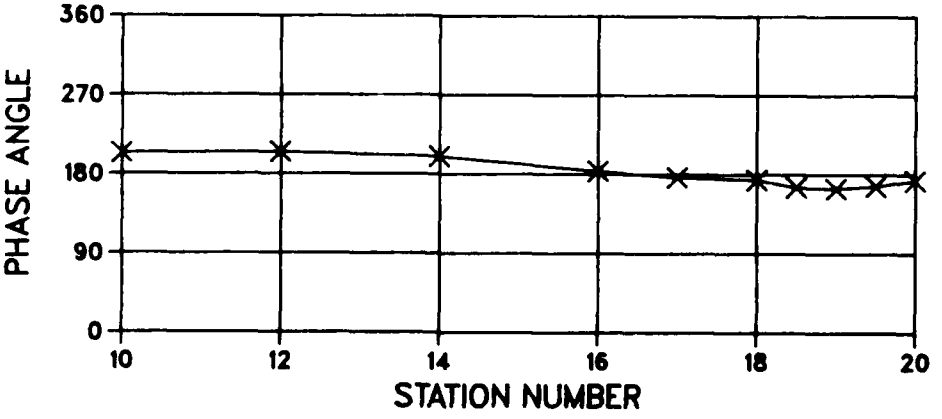

FORCED HEAVE. FN=0.2

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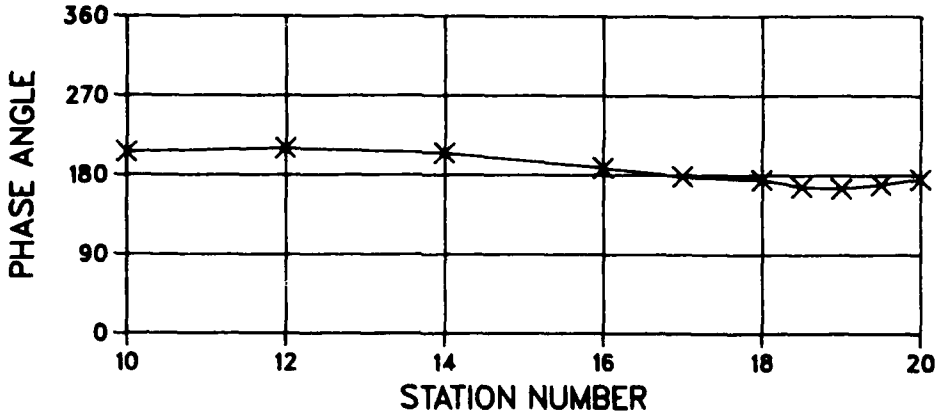

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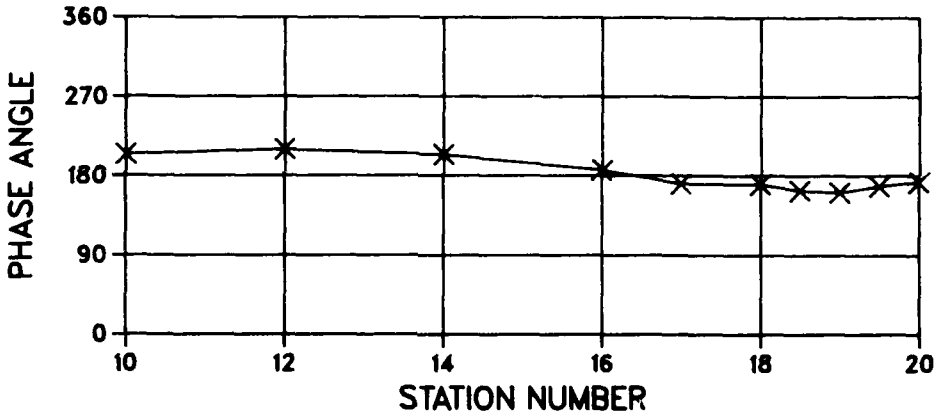

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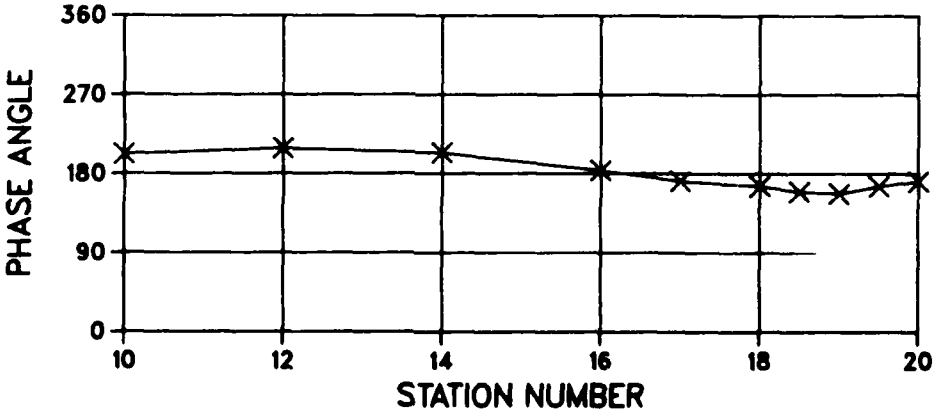
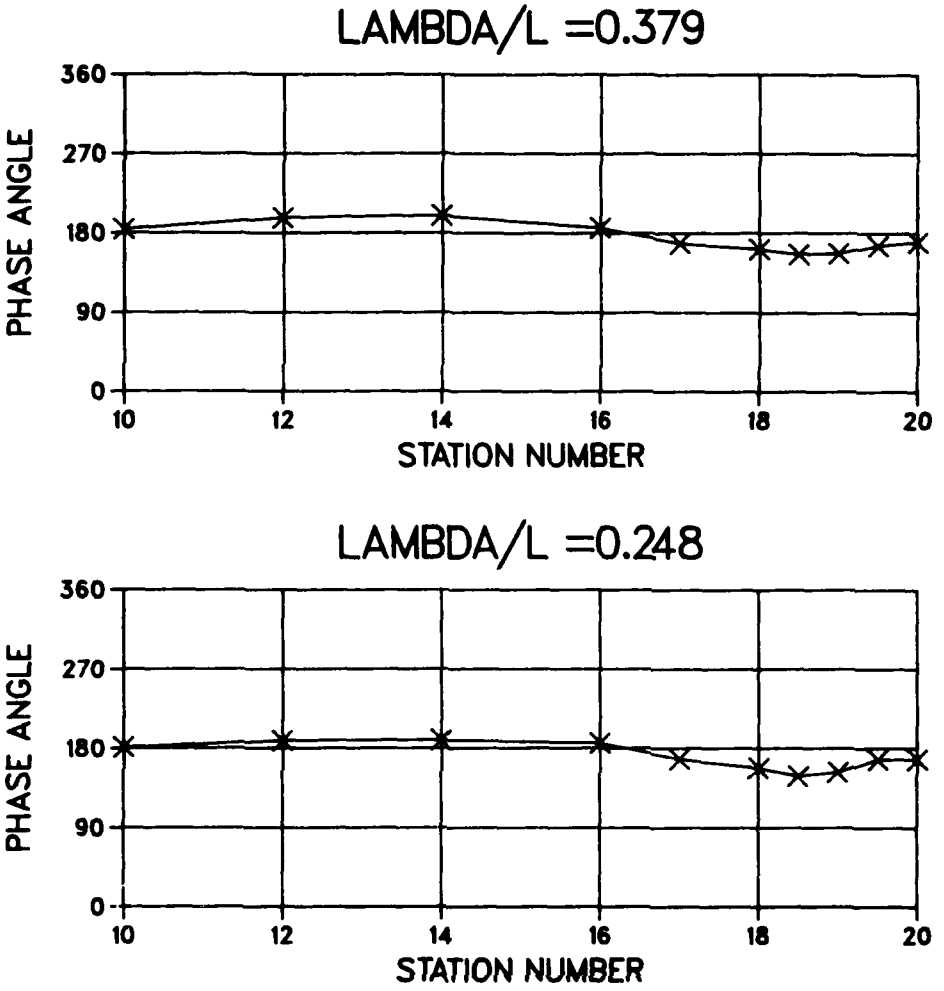
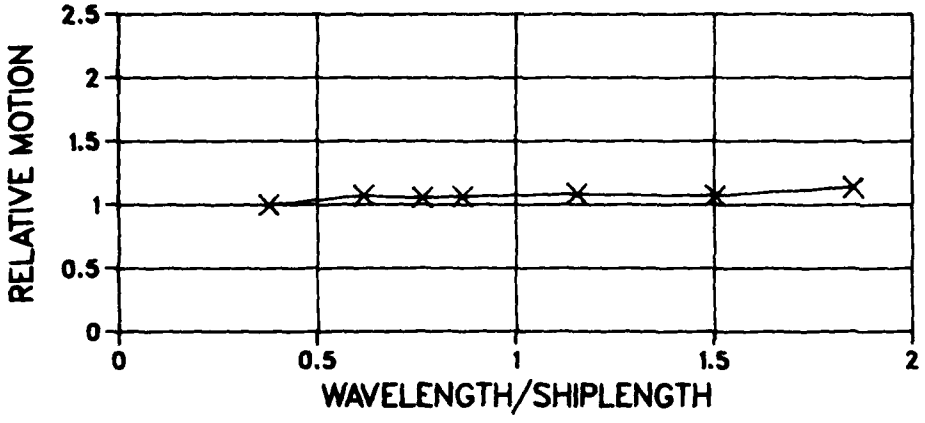


FORCED HEAVE. FN=0.2

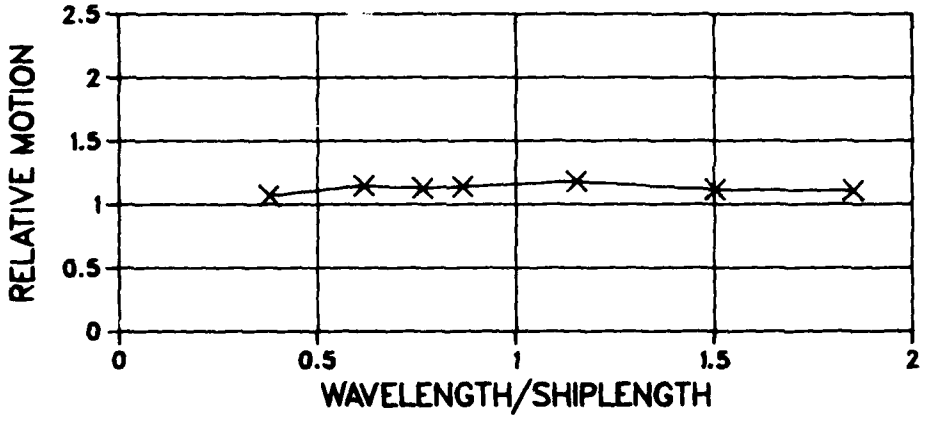


FORCED PITCH. FN=0.2

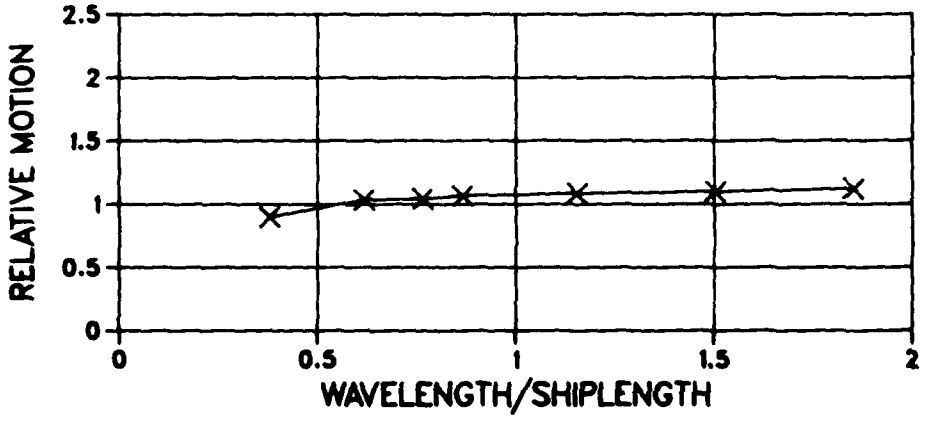
STA.20



STA.19.5

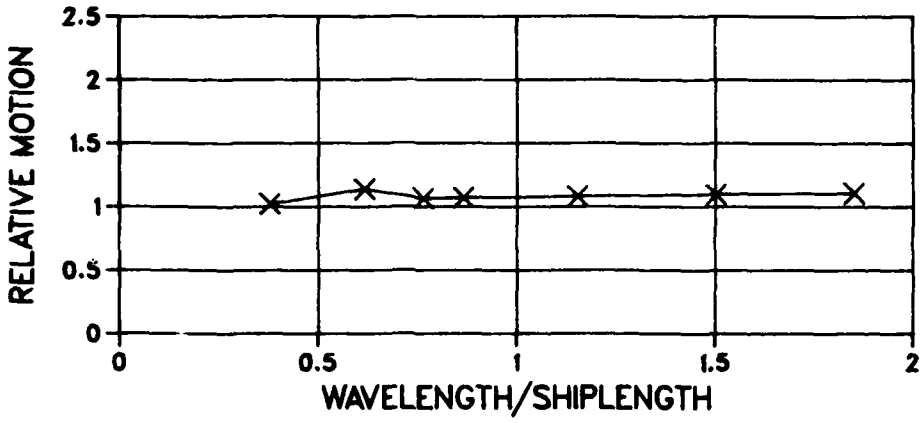


STA.19

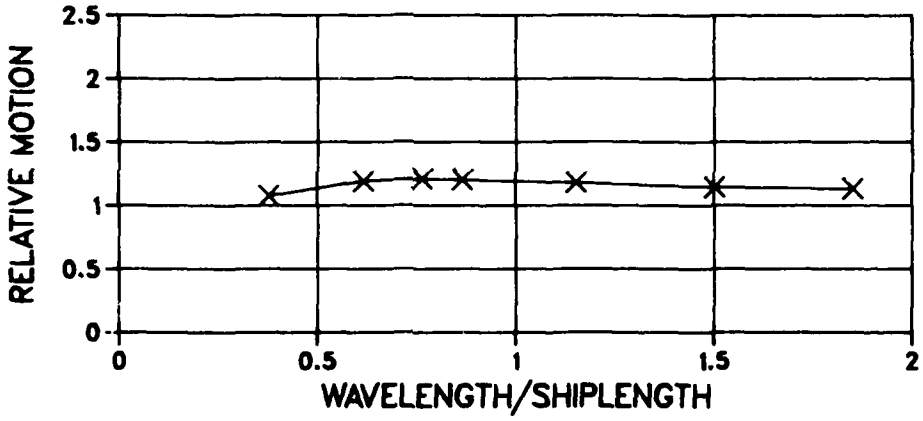


FORCED PITCH. FN=0.2

STA.18.5



STA.18



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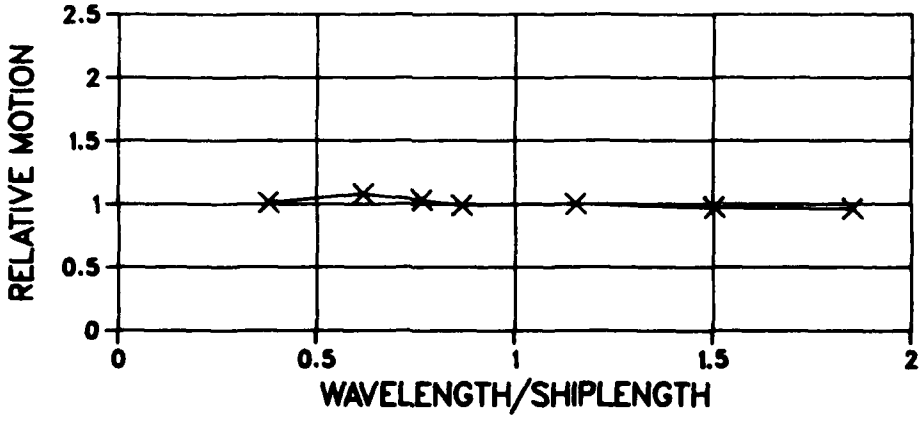
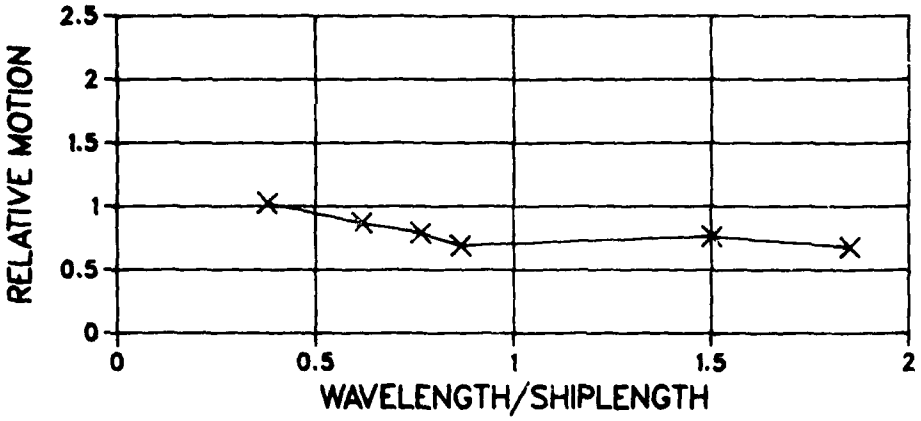


FORCED PITCH. FN=0.2

STA.16



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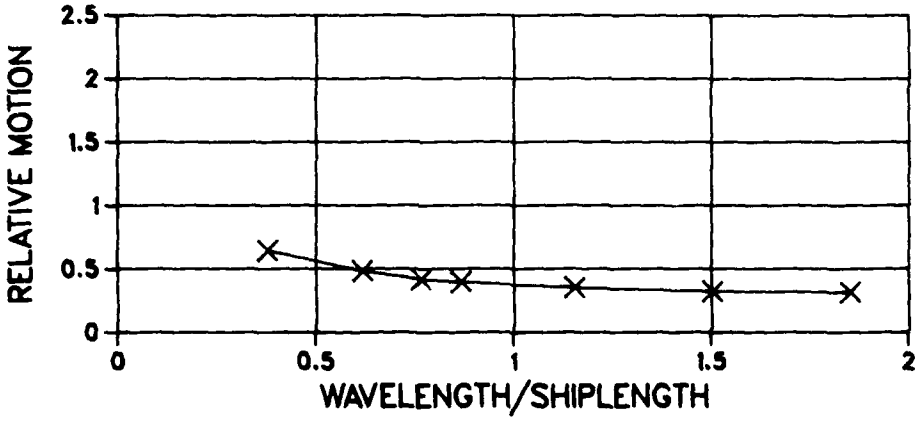
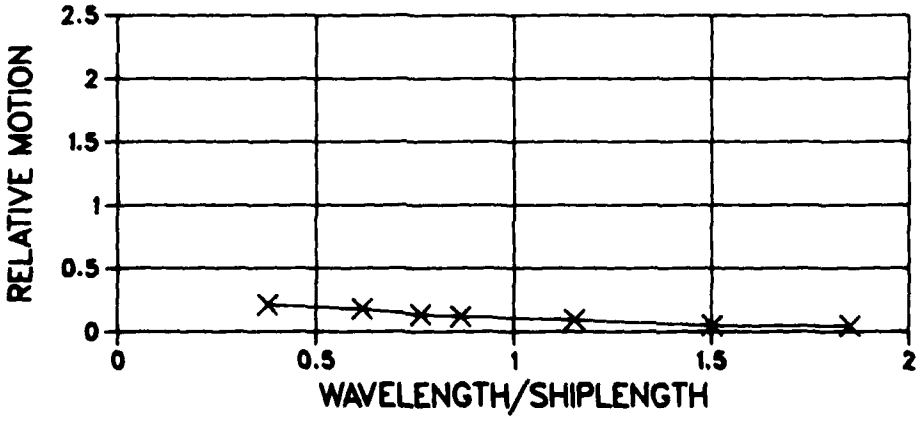
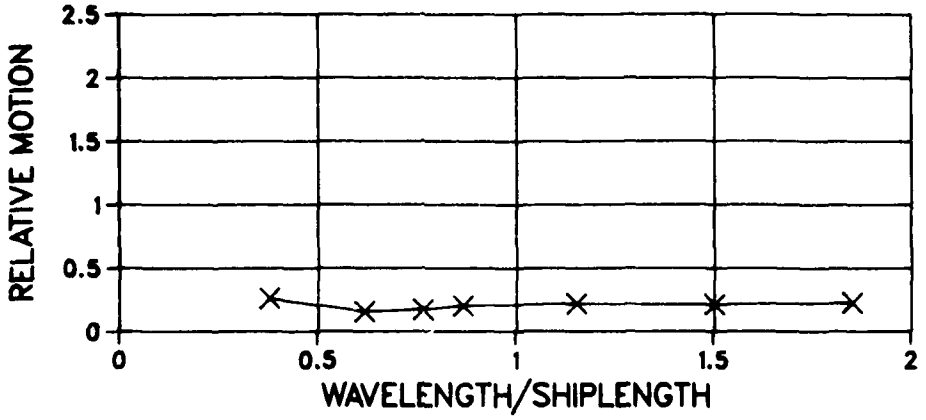


STA.12



FORCED PITCH. FN=0.2

STA.10



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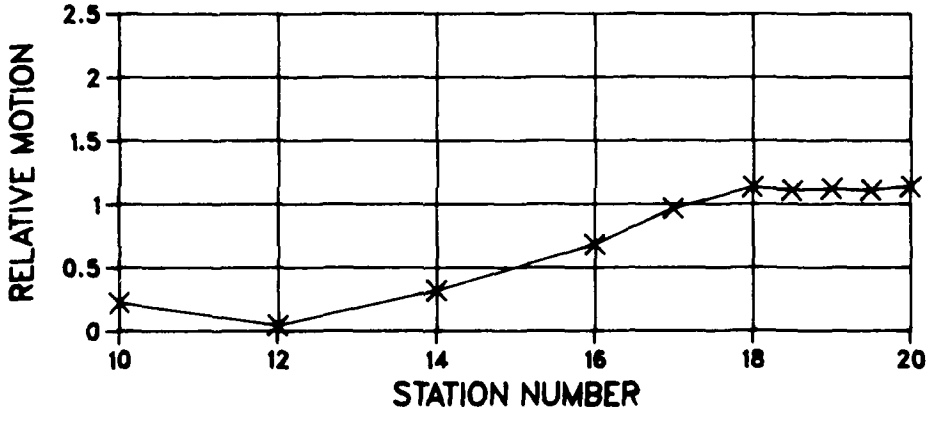

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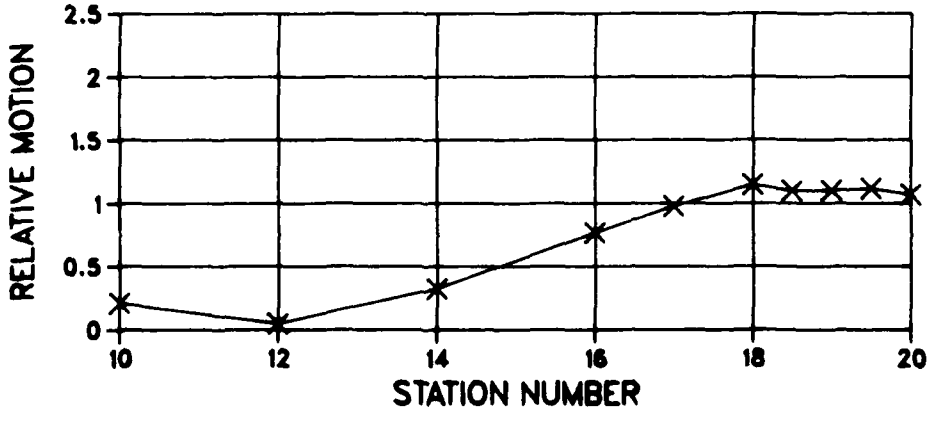

FORCED PITCH. FN=0.2

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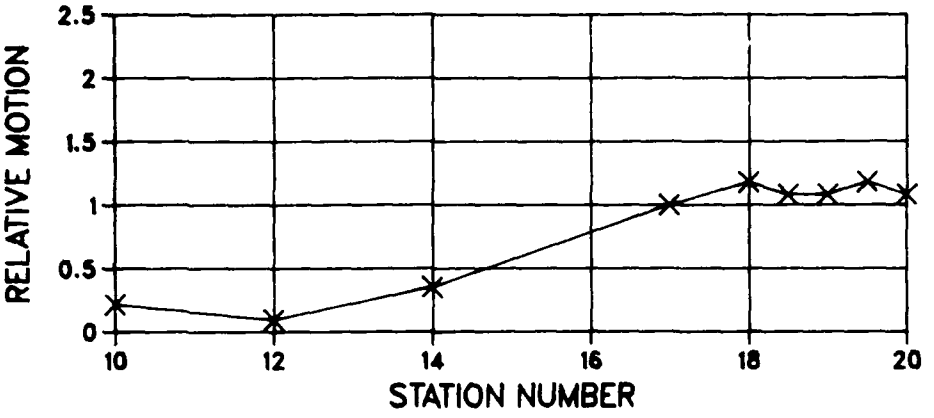

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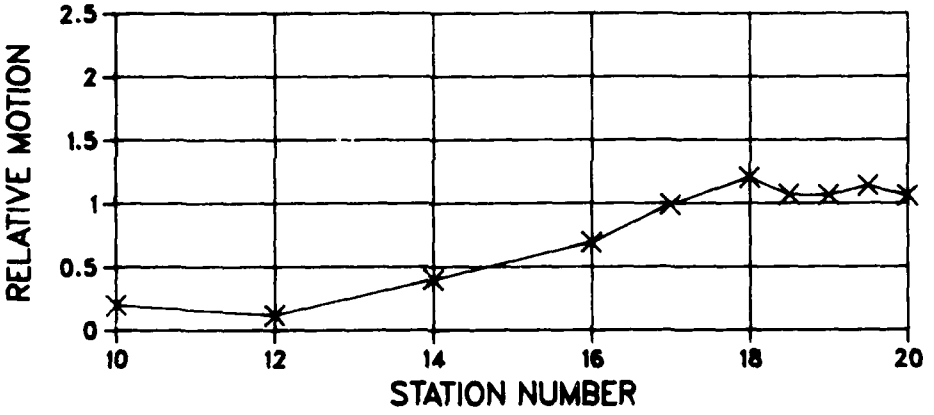

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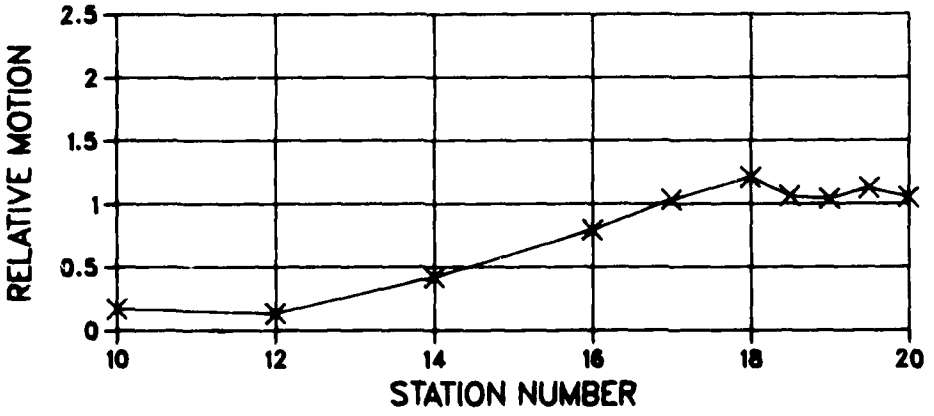

FORCED PITCH. FN=0.2

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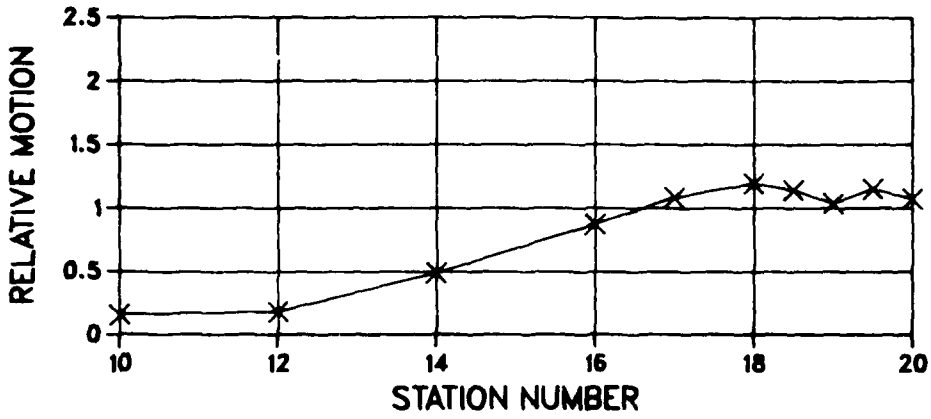

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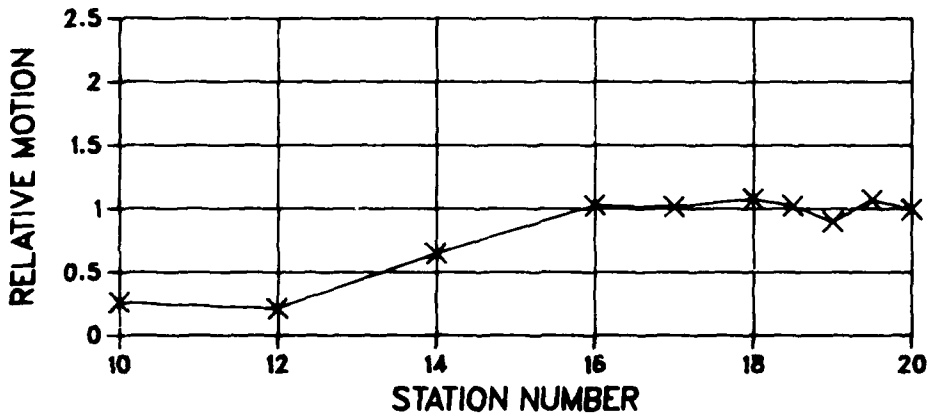
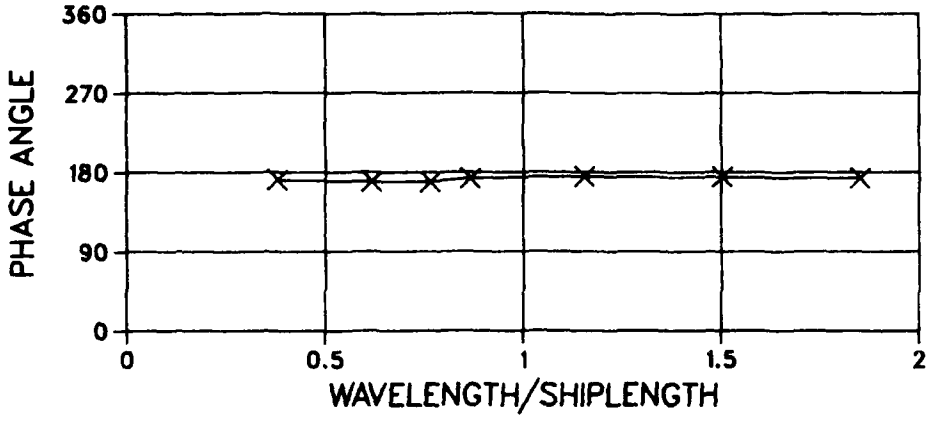
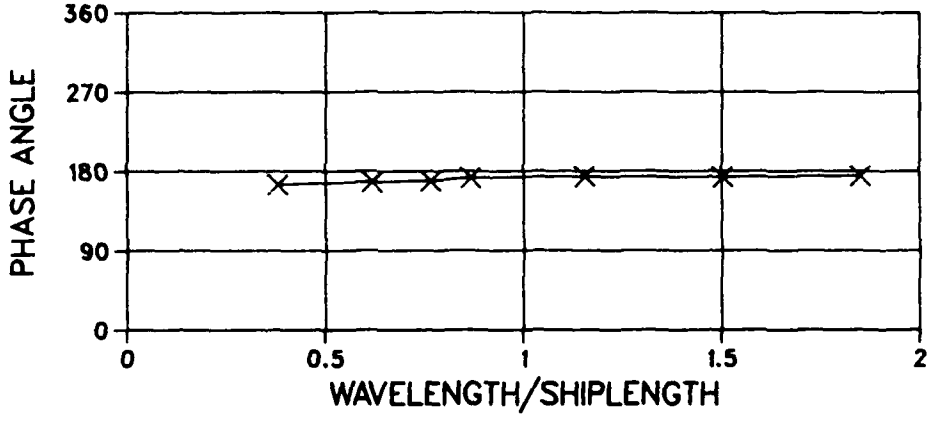


FORCED PITCH. FN=0.2

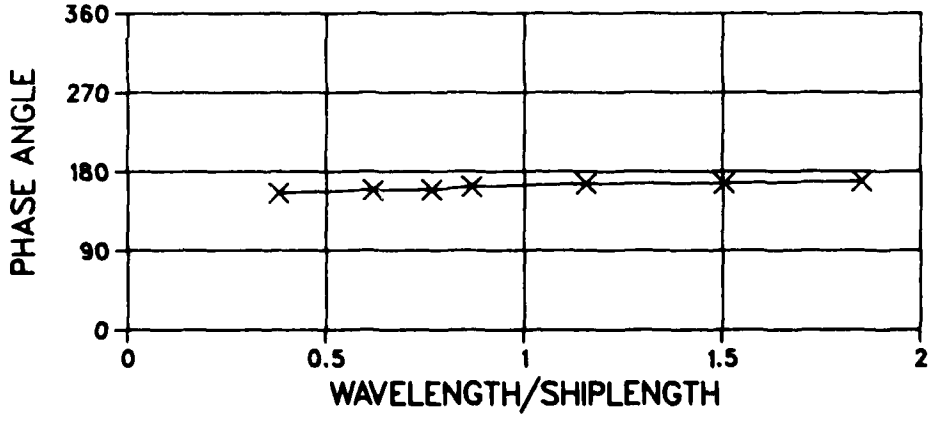
STA.20



STA.19.5



STA.19



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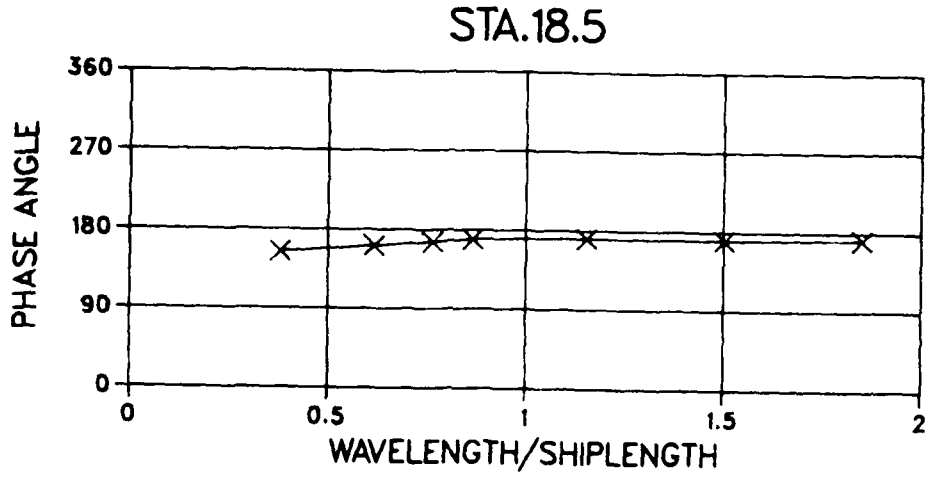

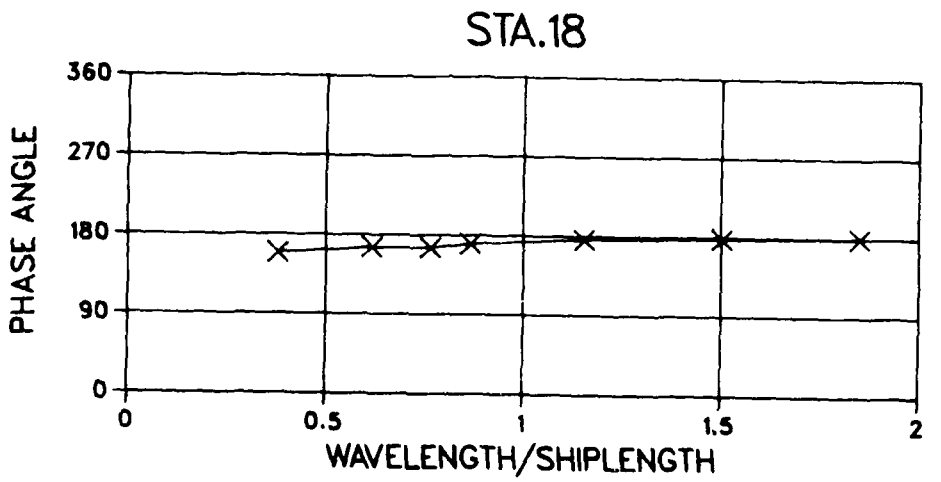

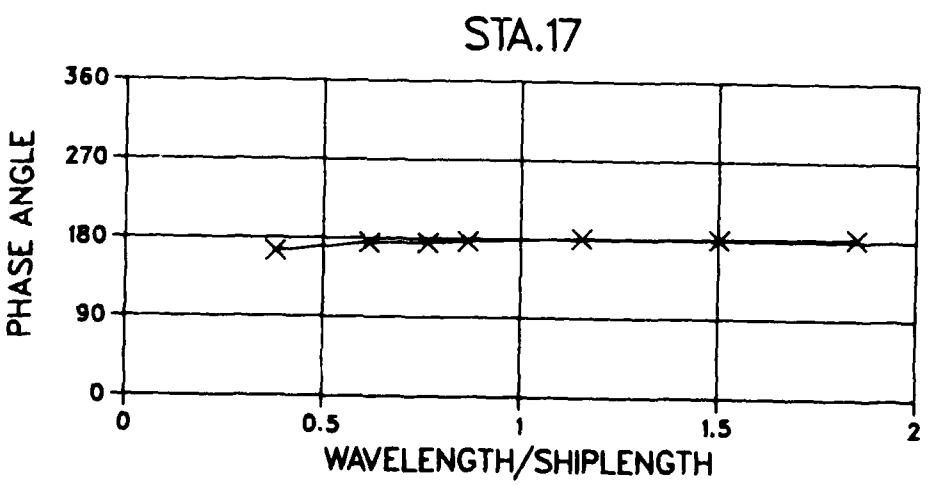

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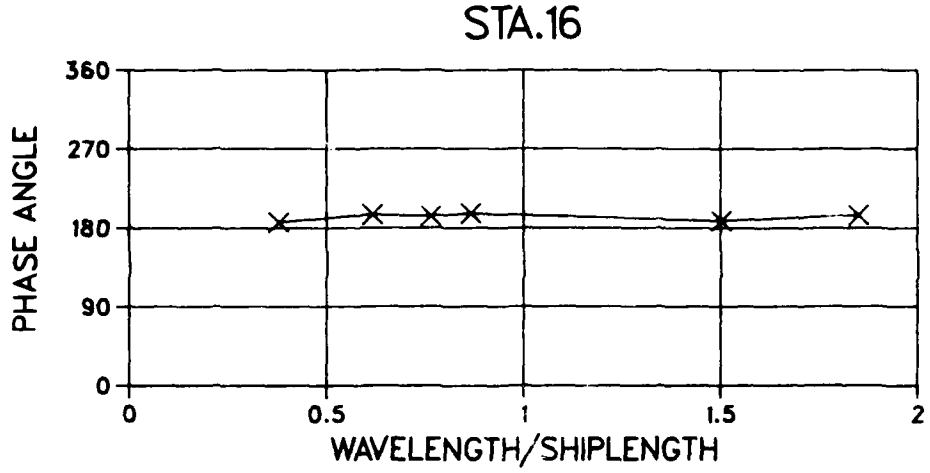

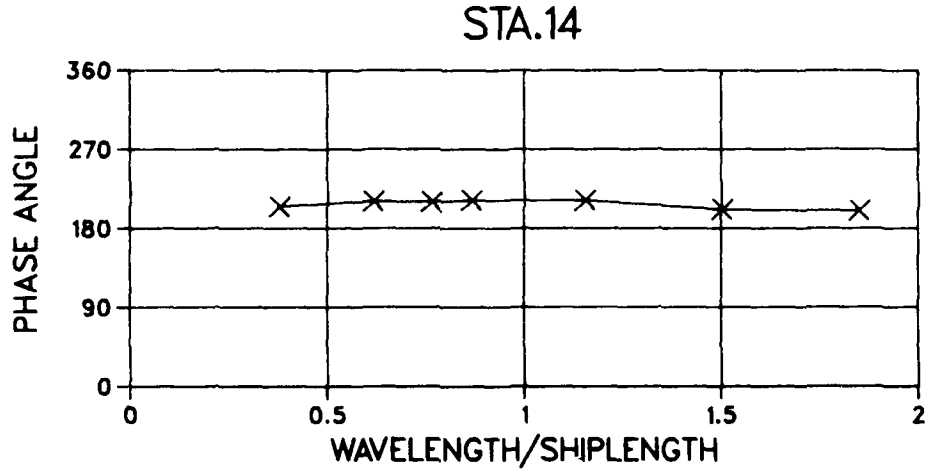

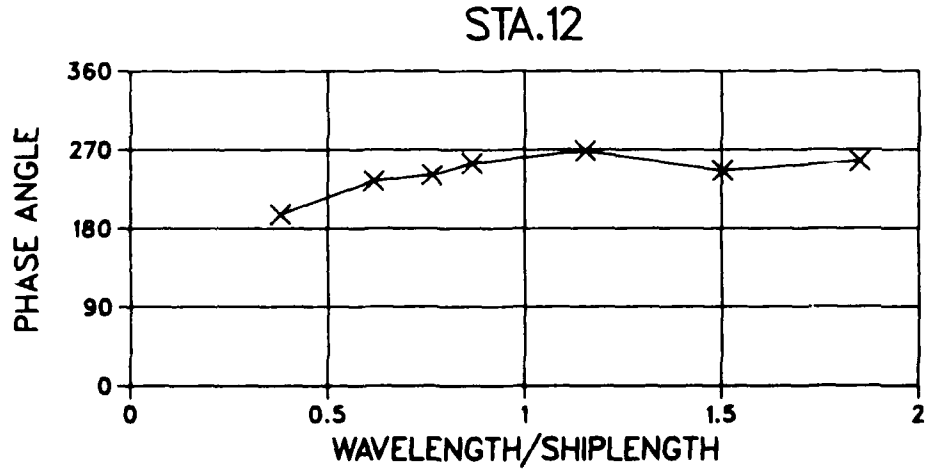

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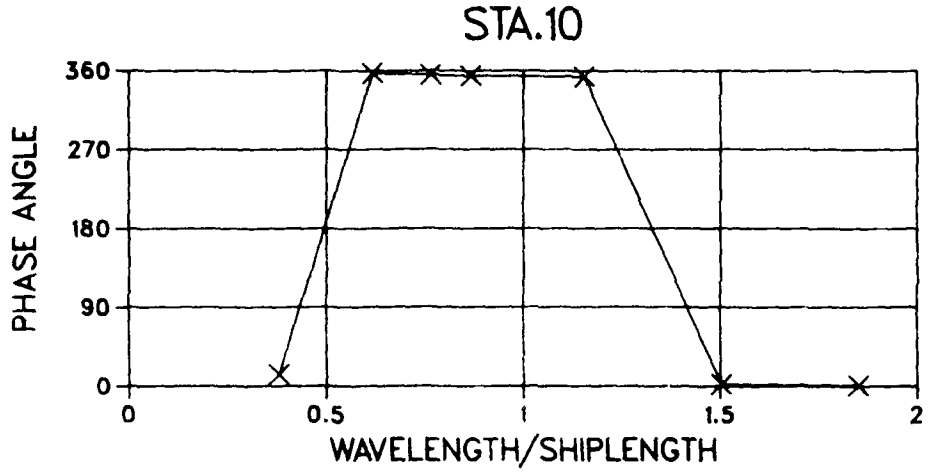

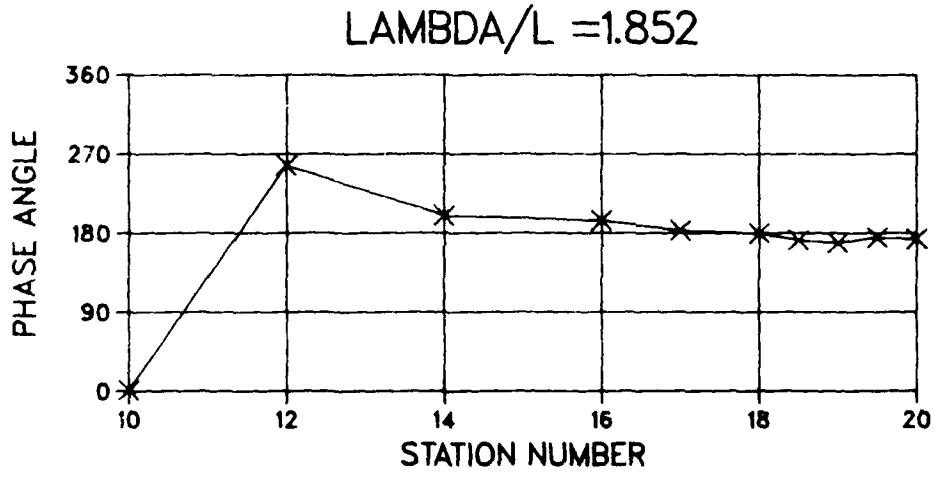

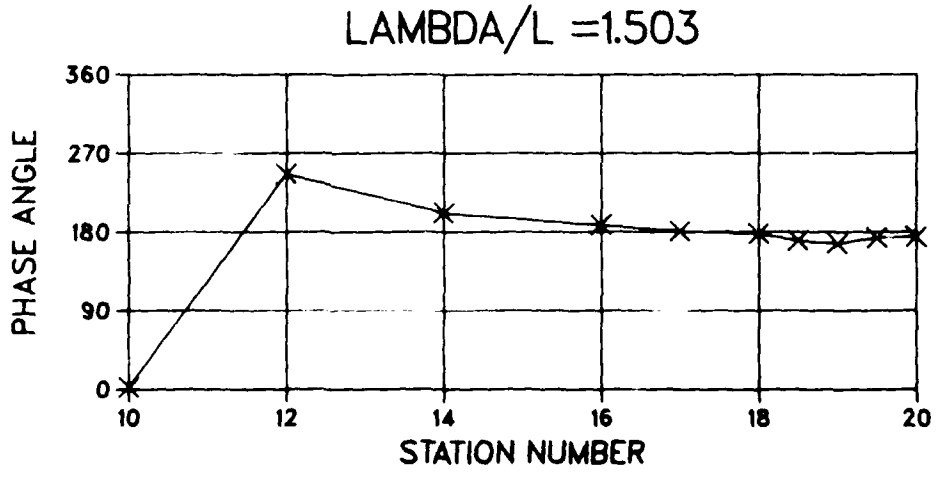

FORCED PITCH. FN=0.2

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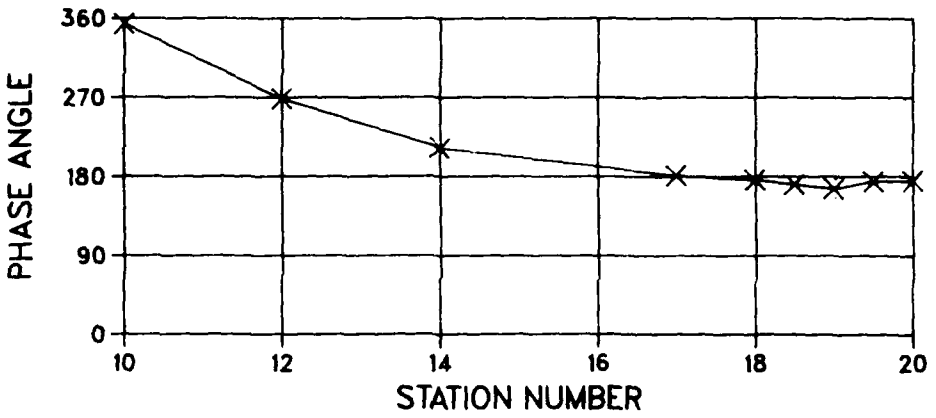
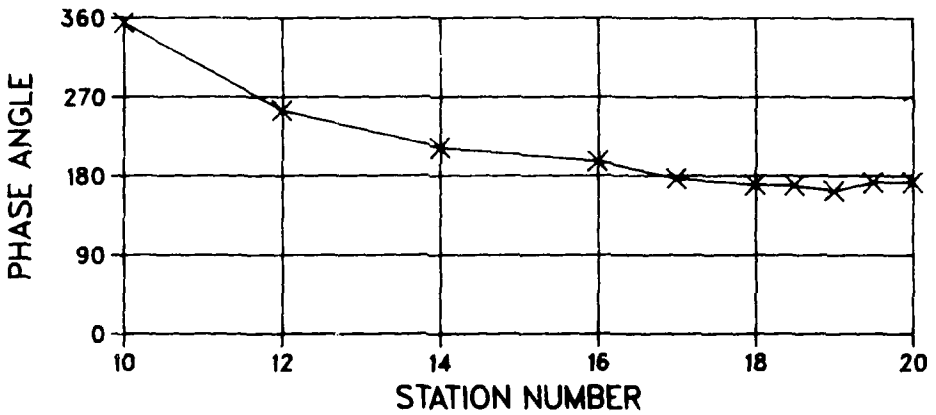


LAMBDA/L =0.867



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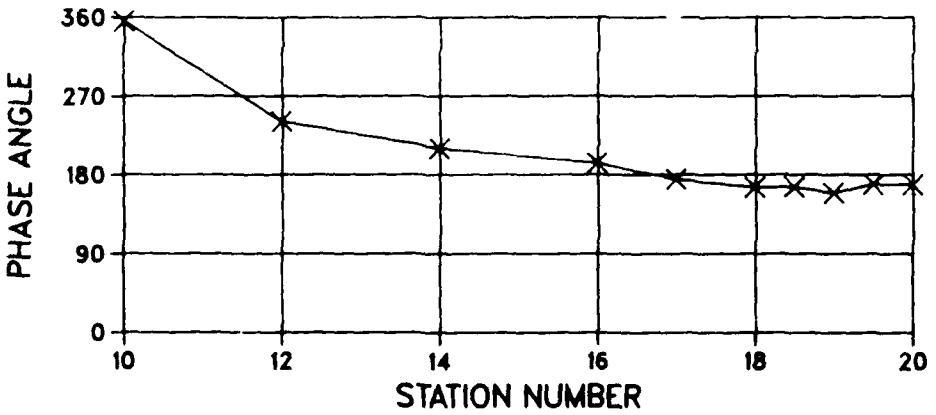
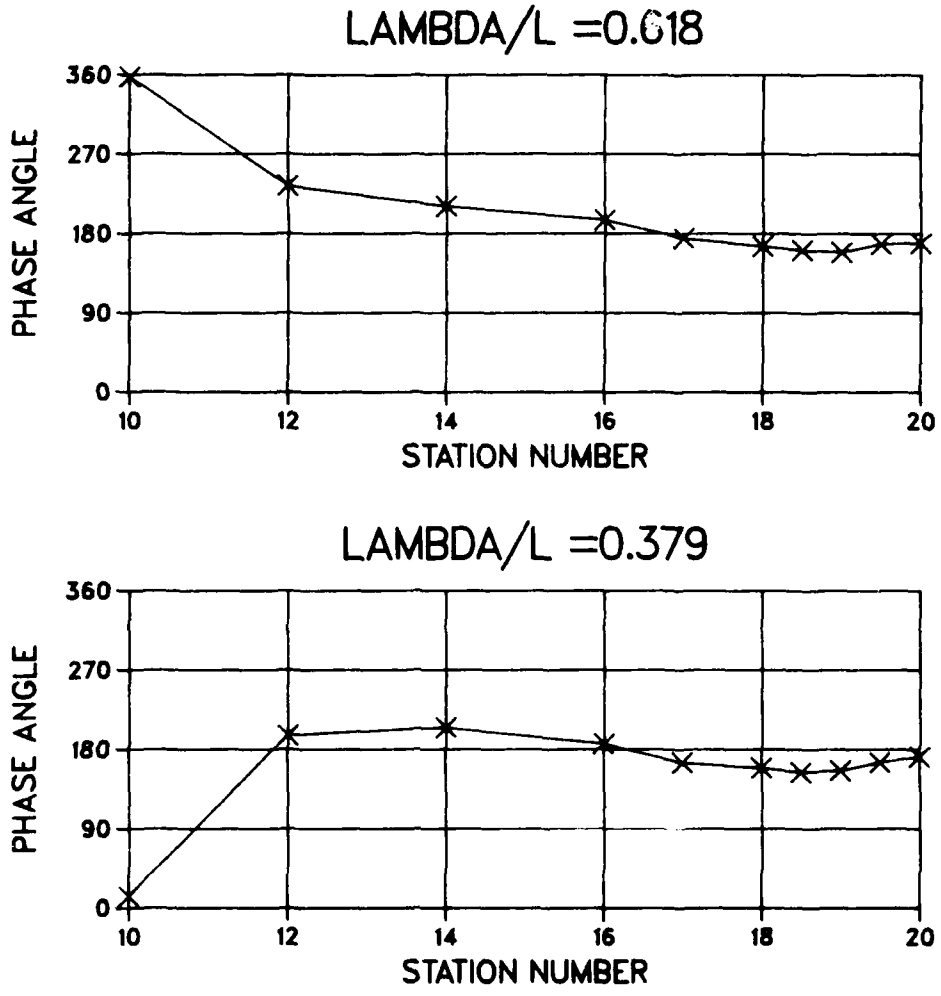
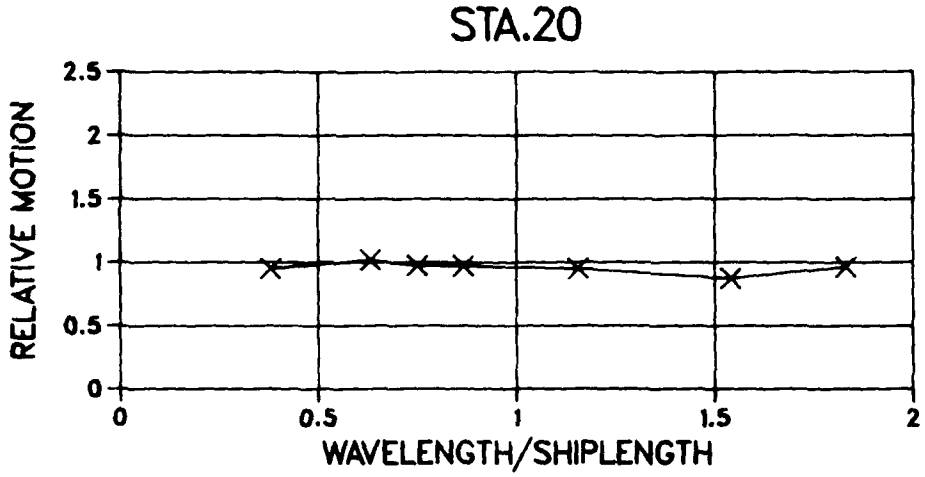
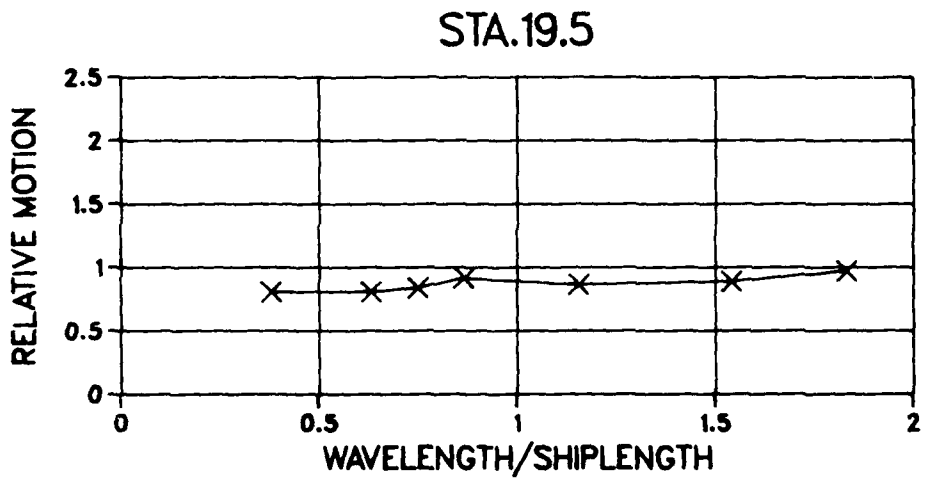


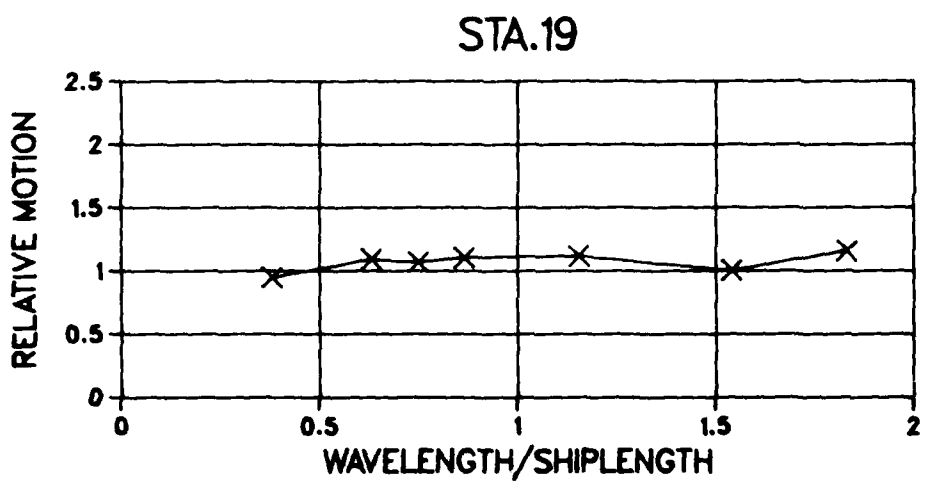
FORCED PITCH. FN=0.2



FORCED HEAVE. FN=0.3

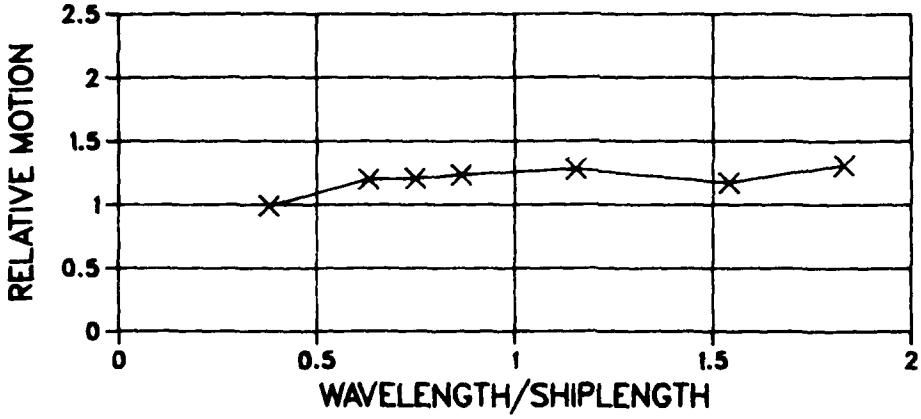




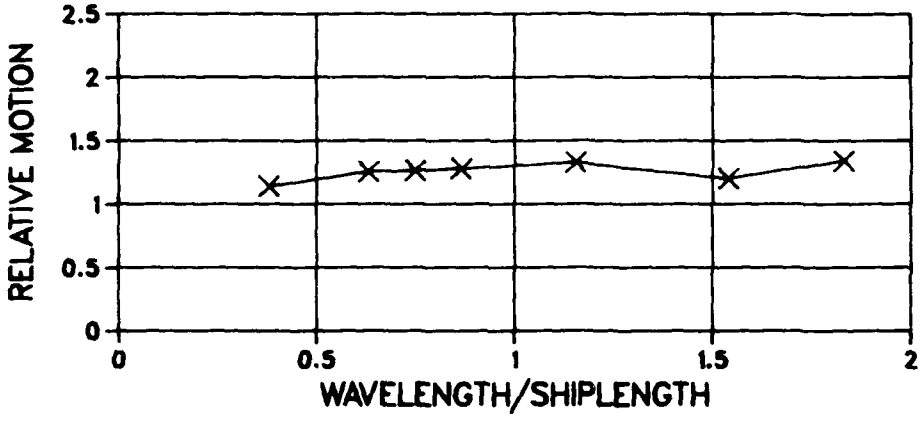


FORCED HEAVE. FN=0.3

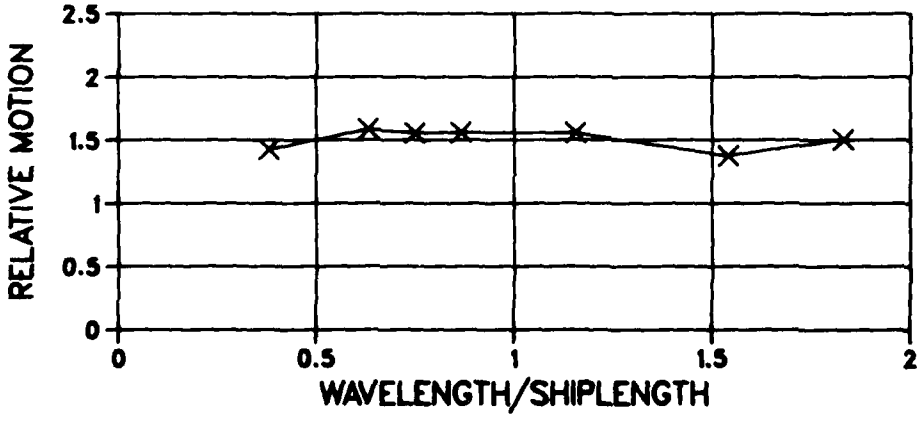
STA.18.5



STA.18



STA.17



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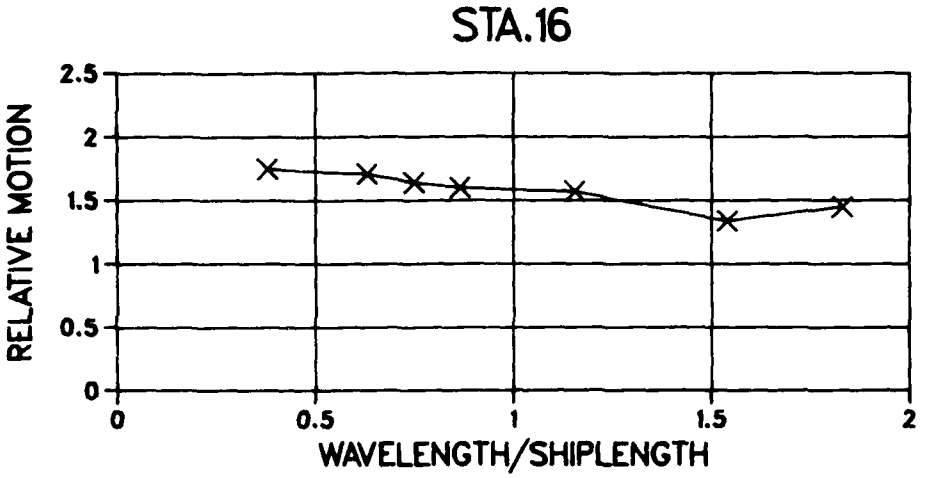
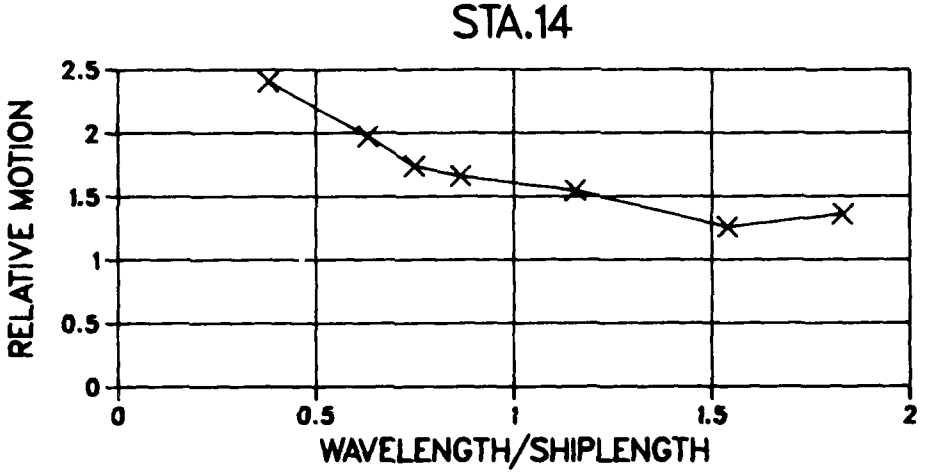
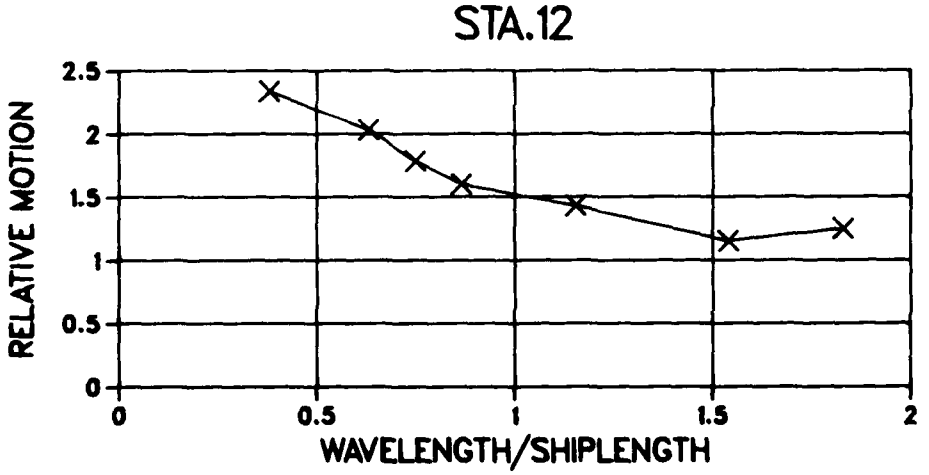
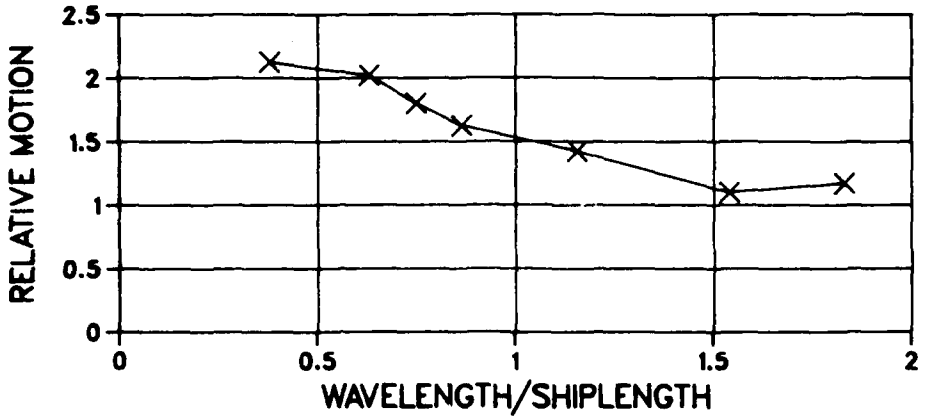




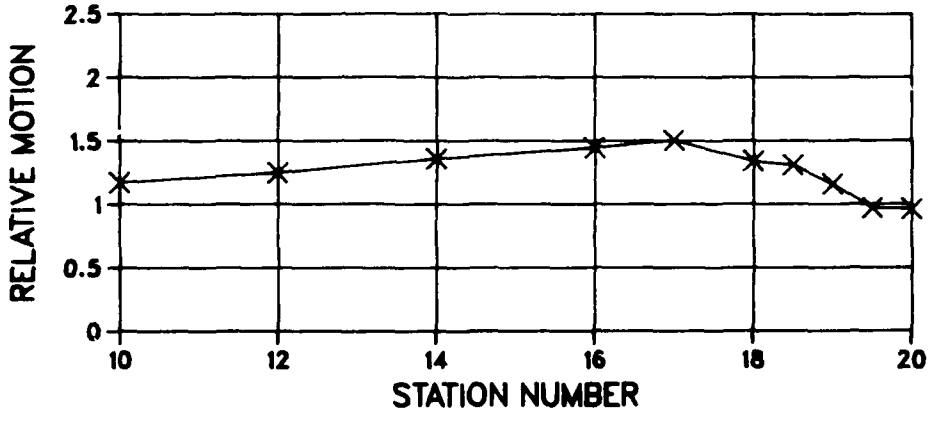


FORCED HEAVE. FN=0.3

STA.10



LAMBDA/L =1.831



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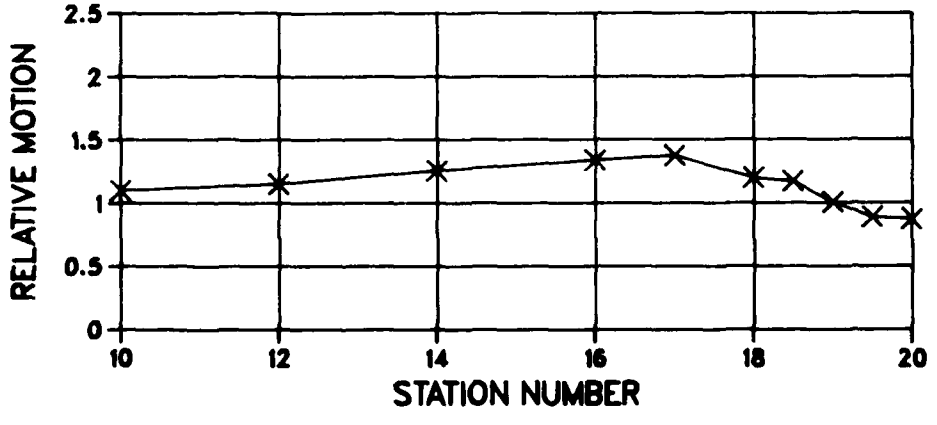

FORCED HEAVE. FN=0.3

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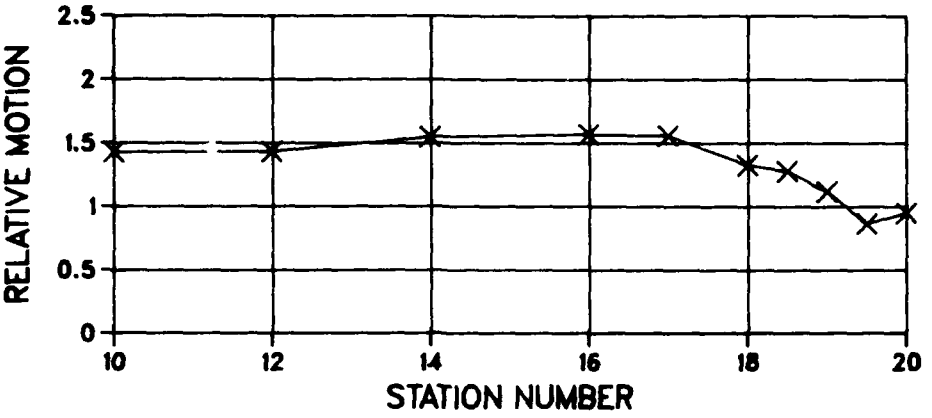

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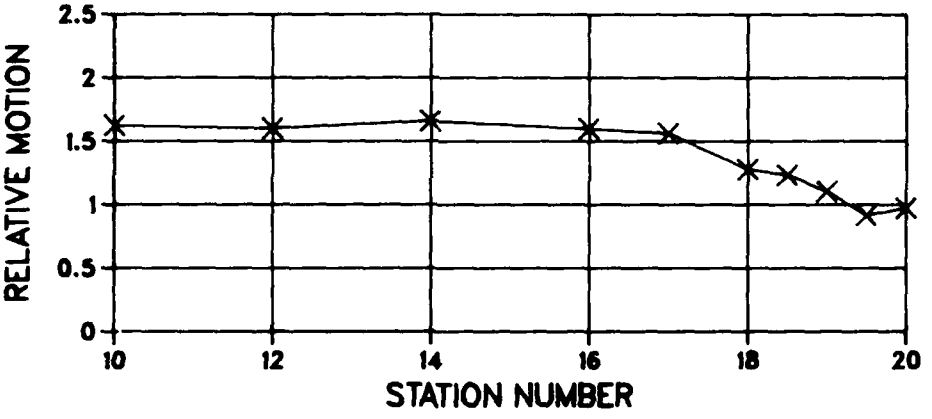

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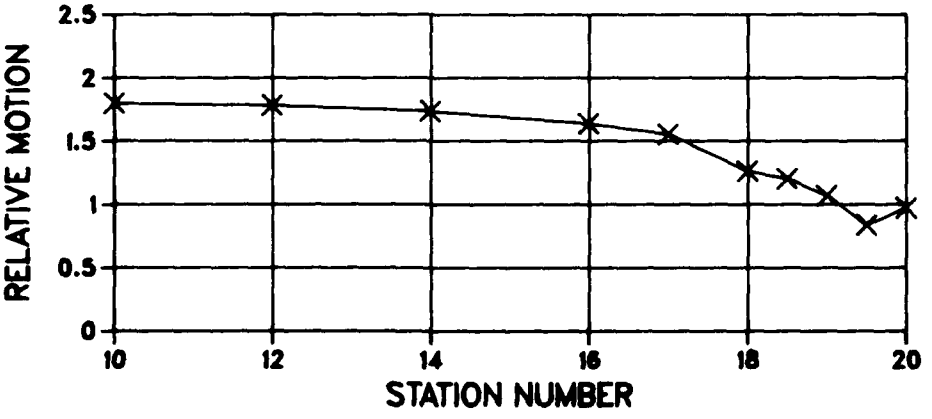
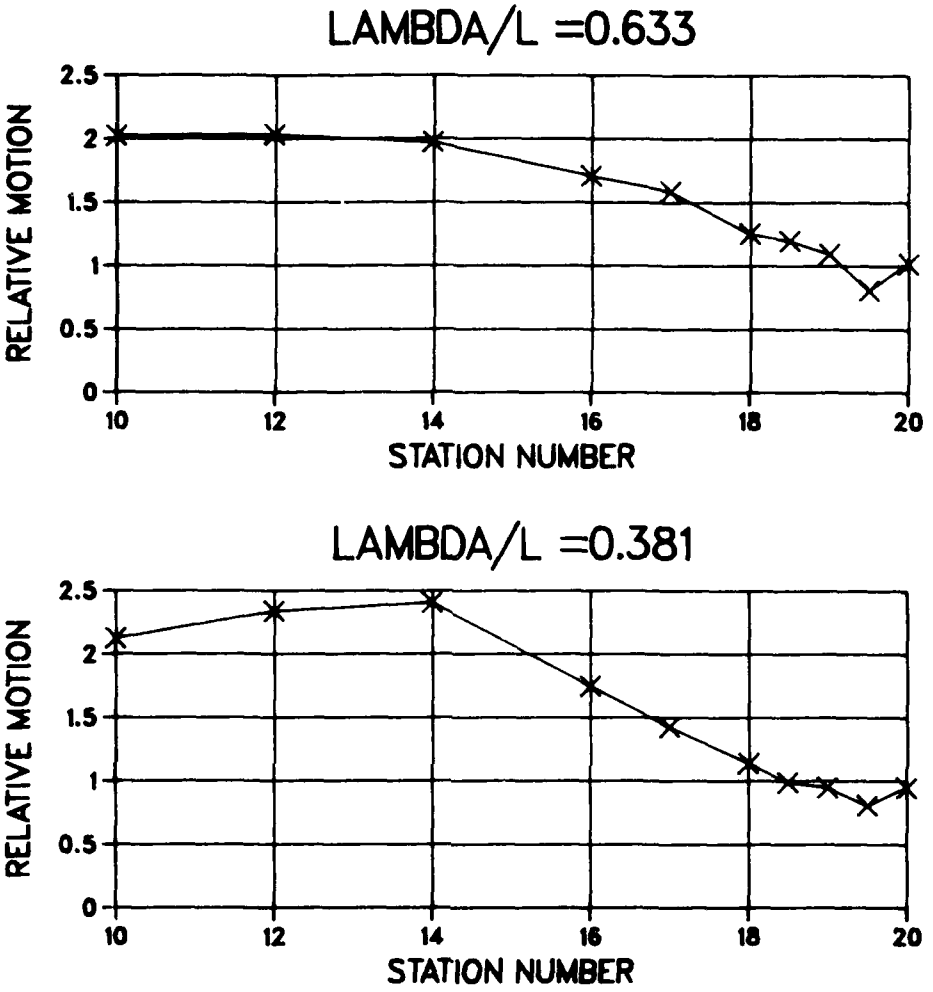


FORCED HEAVE. FN=0.3



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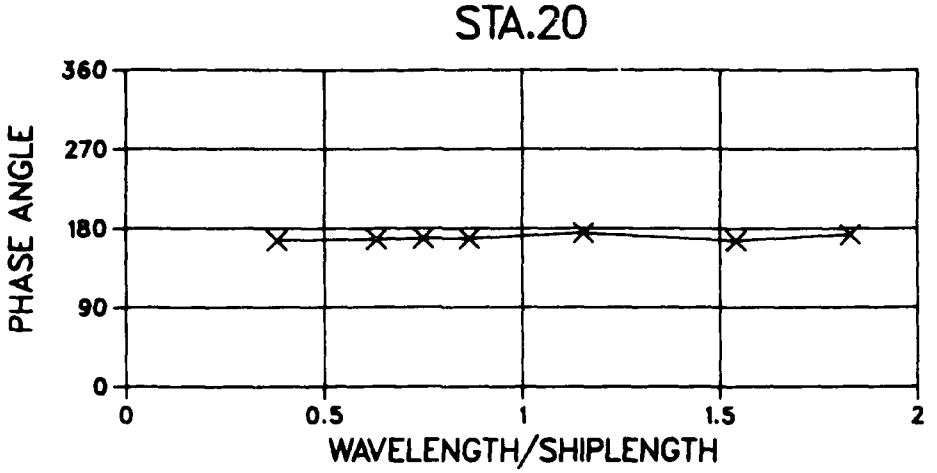
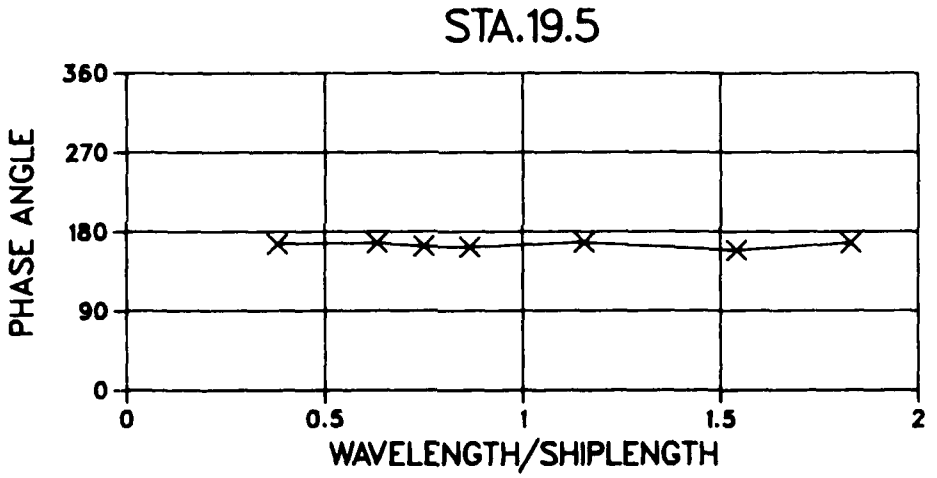
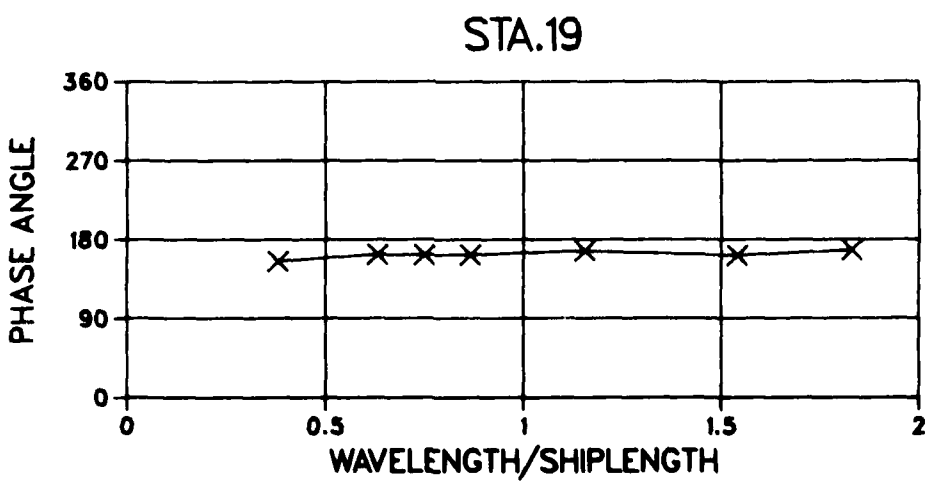
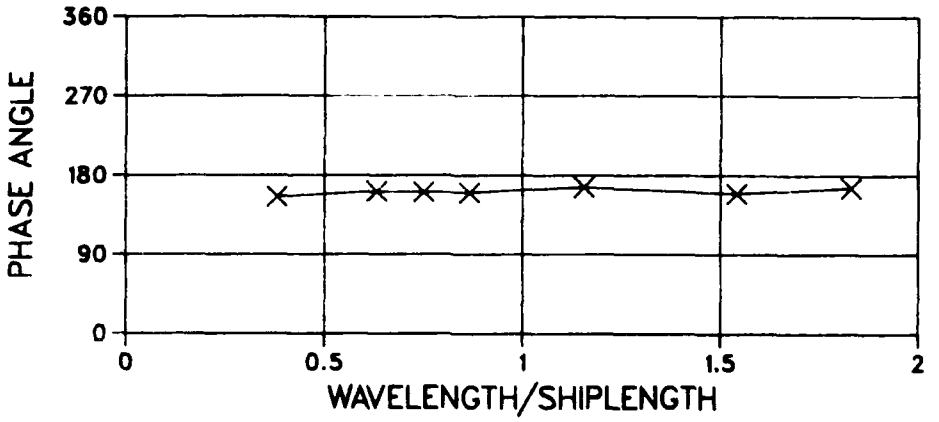






FORCED HEAVE. FN=0.3

STA.18.5



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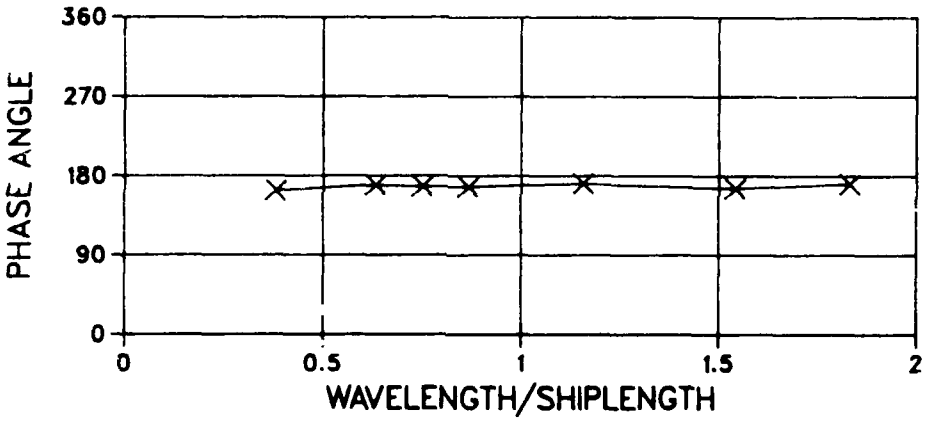
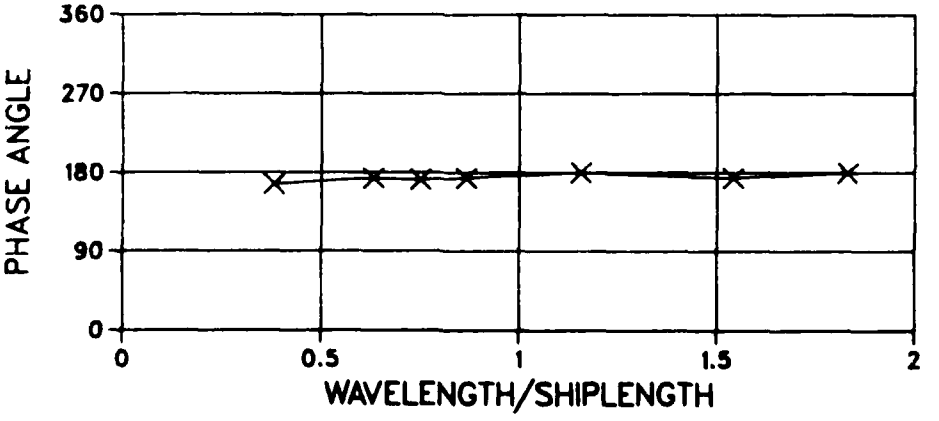
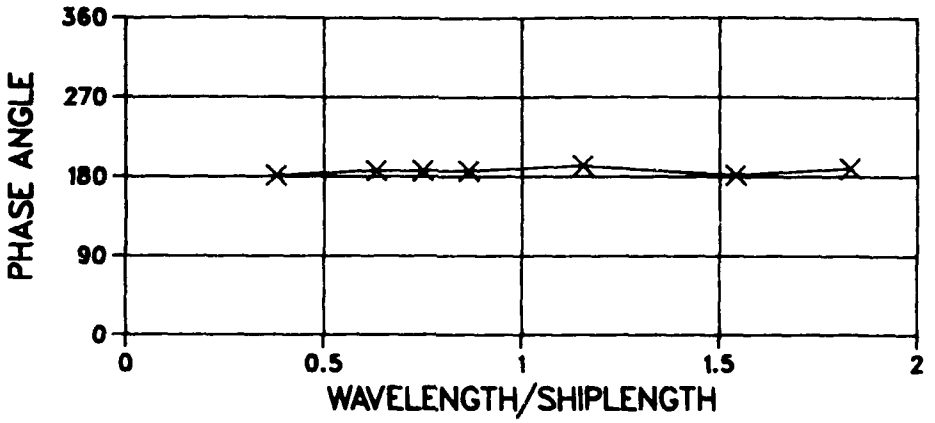


STA.17

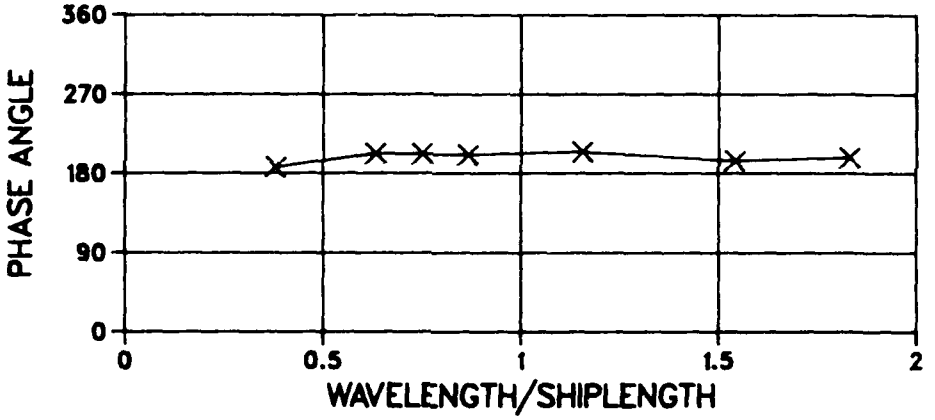


FORCED HEAVE. FN=0.3

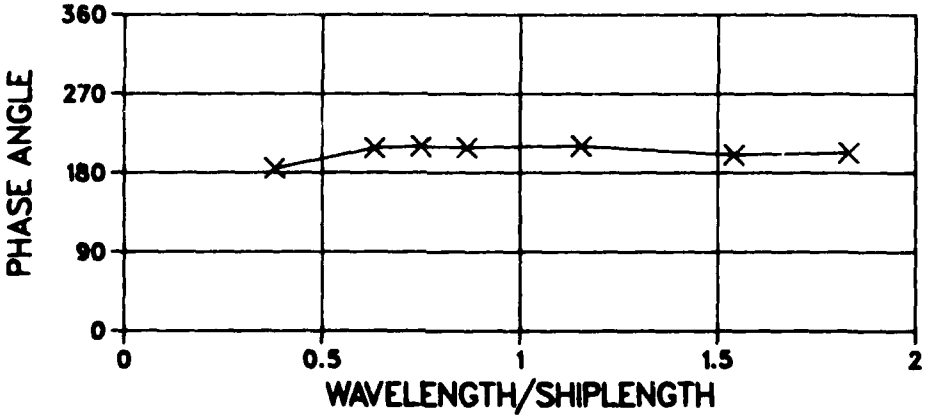
STA.16



STA.14

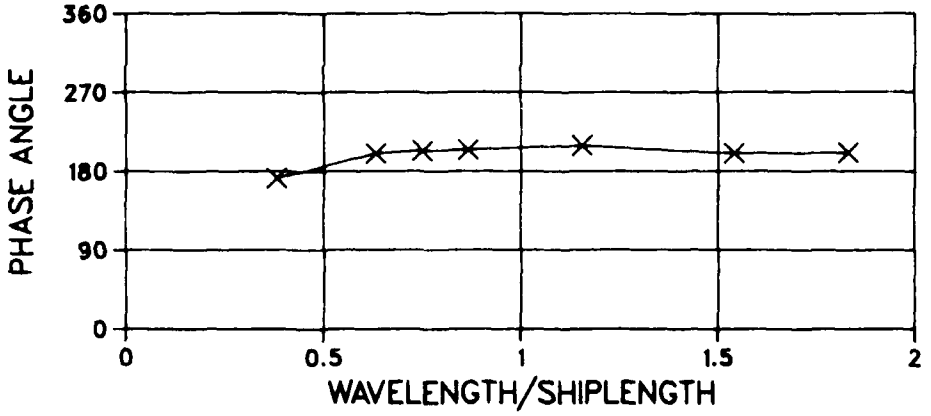


STA.12



FORCED HEAVE. FN=0.3

STA.10



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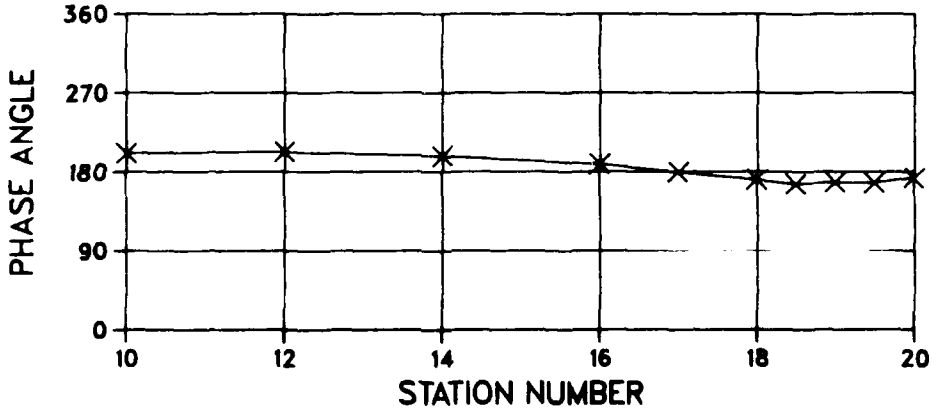

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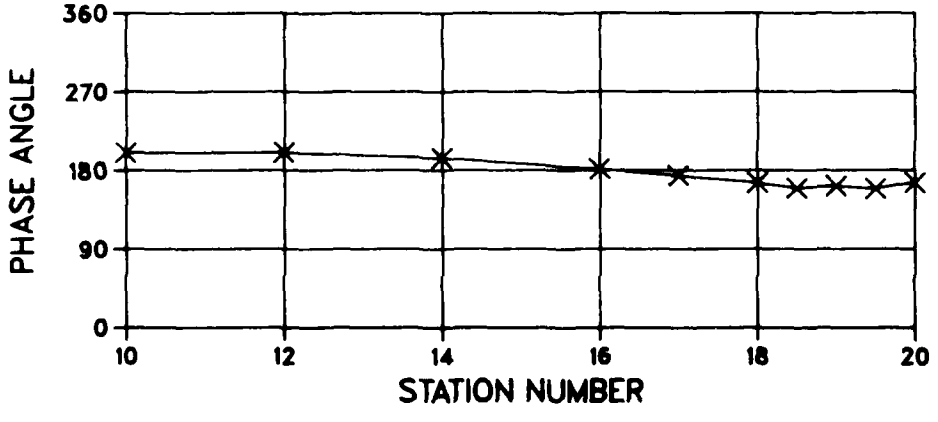

FORCED HEAVE. FN=0.3

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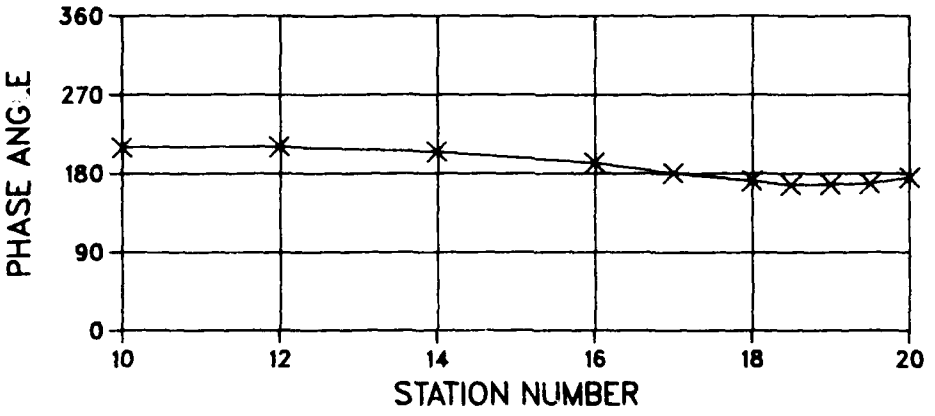

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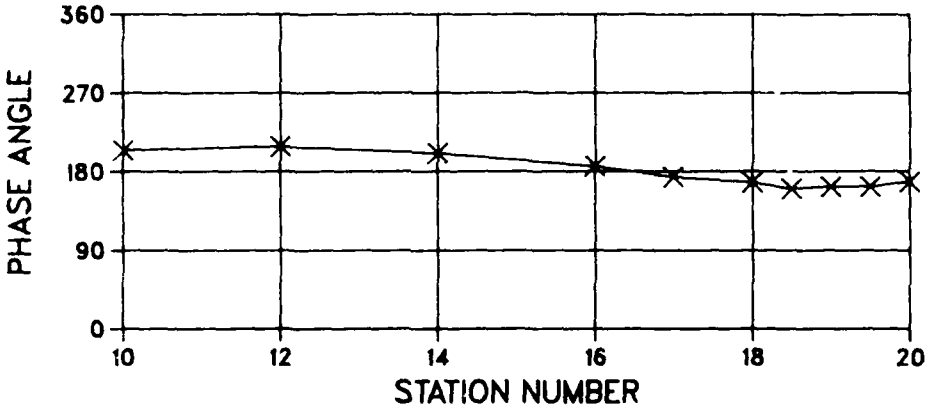

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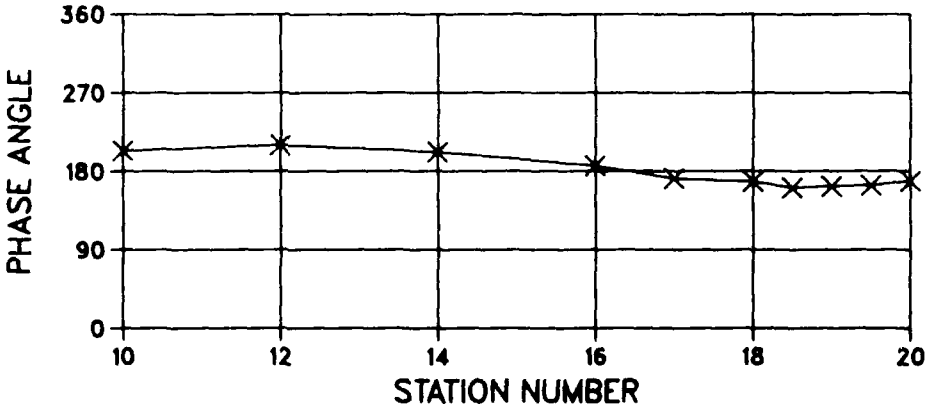

FORCED HEAVE. FN=0.3

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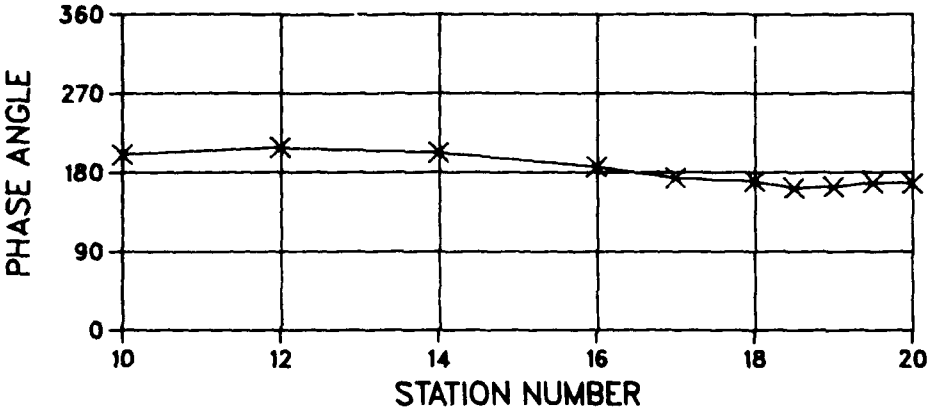

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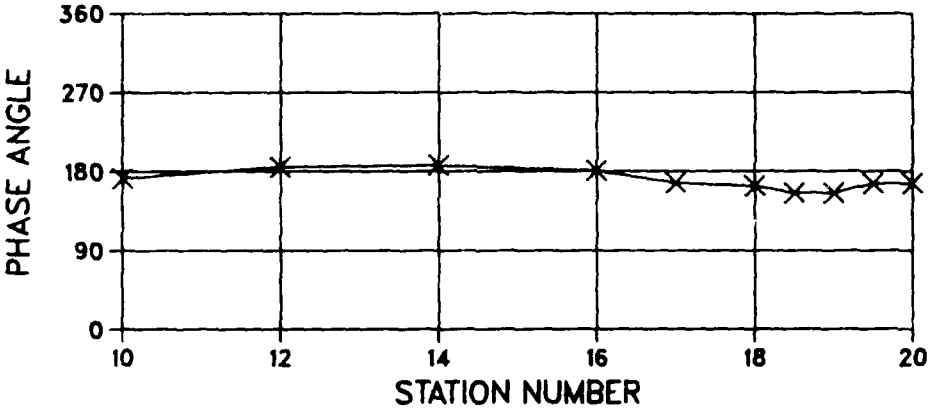
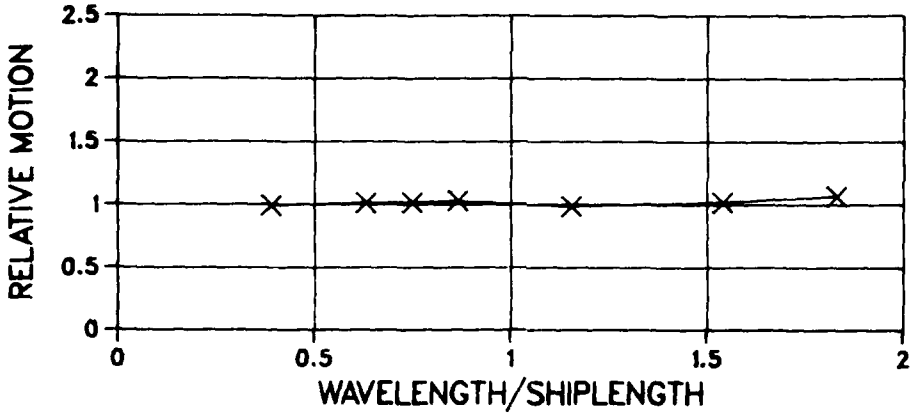
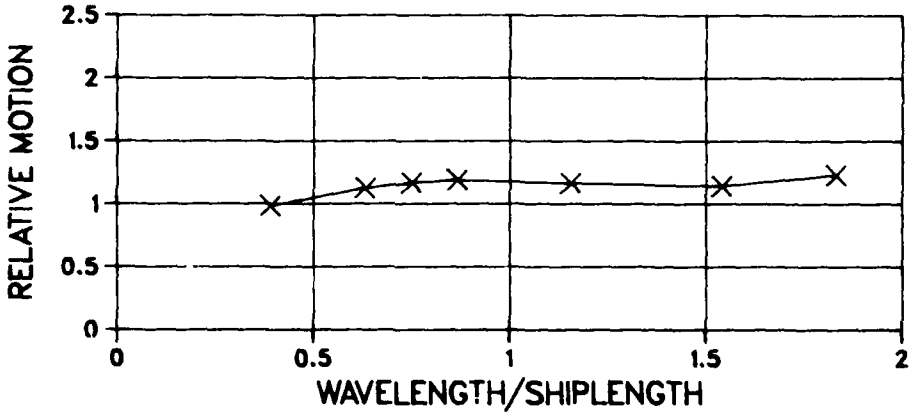


FORCED PITCH. FN=0.3

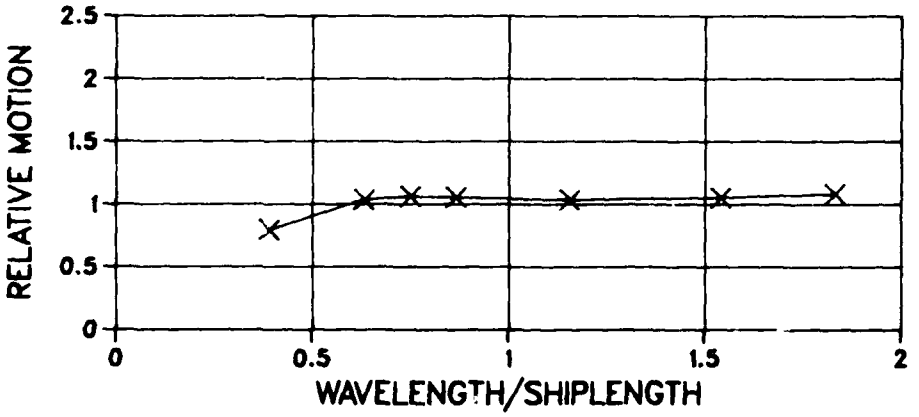
STA.20



STA.19.5



STA.19



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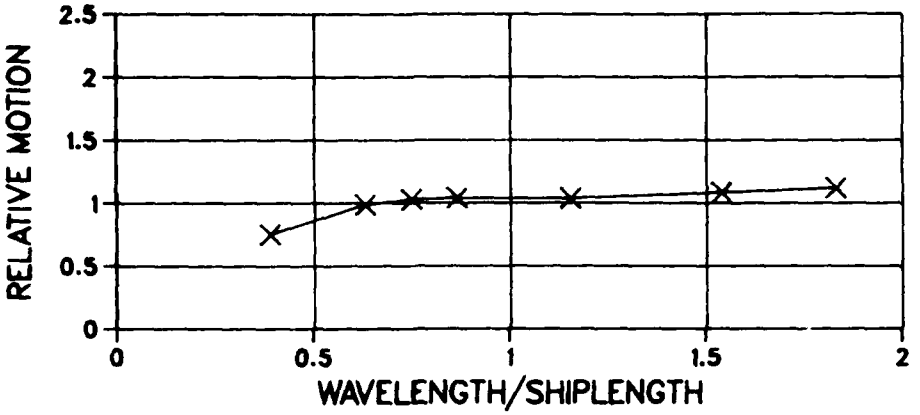
STA.18.5



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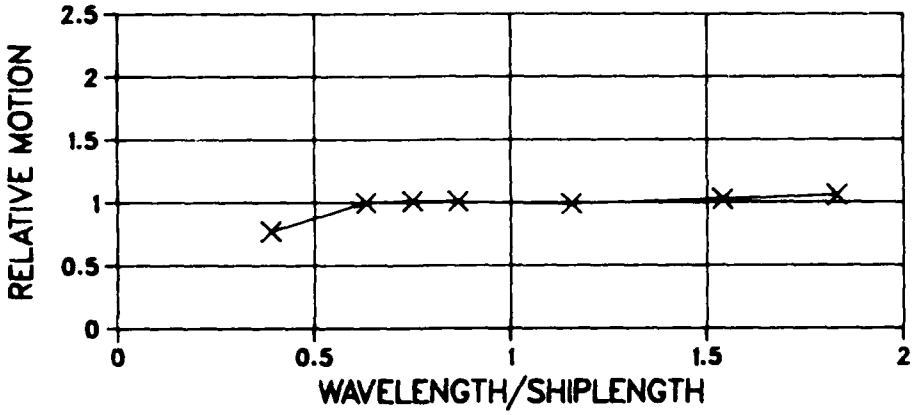

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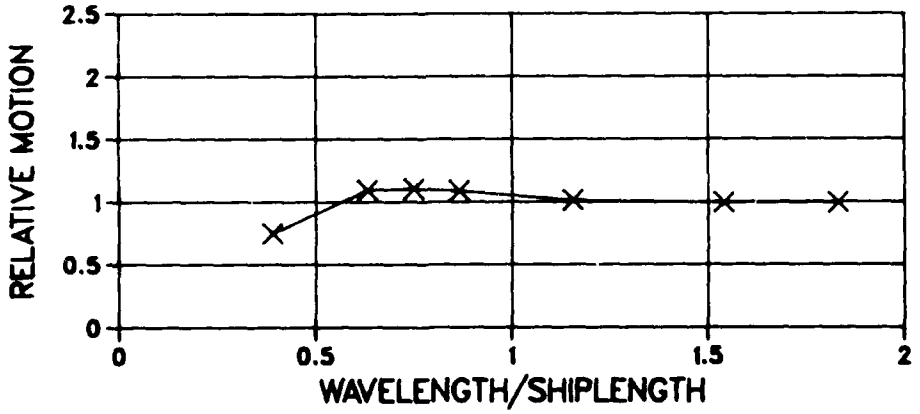

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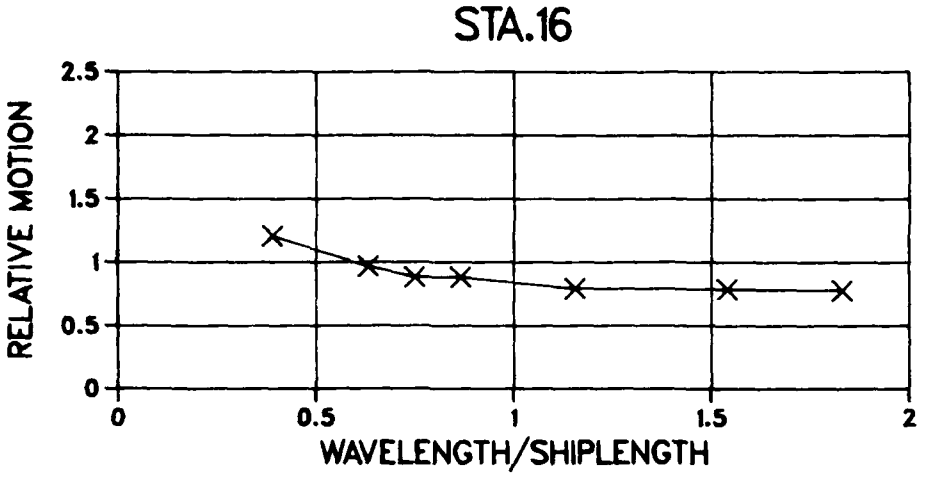

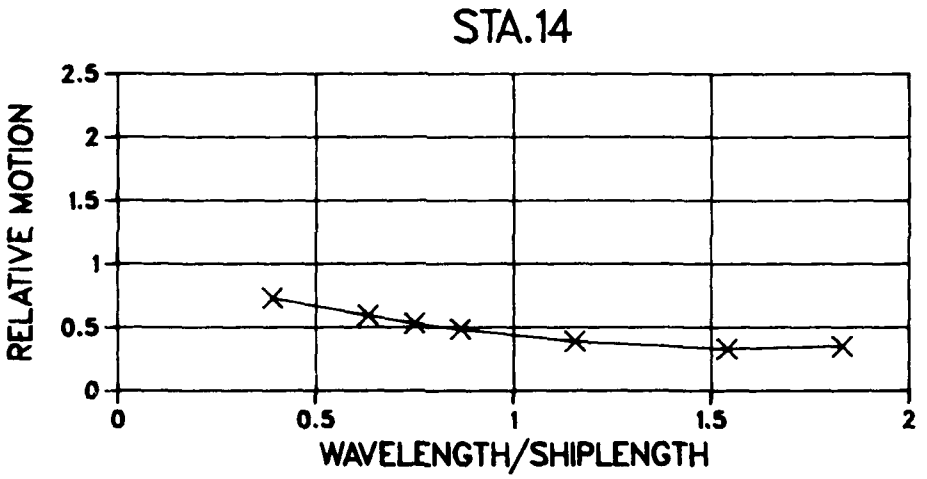

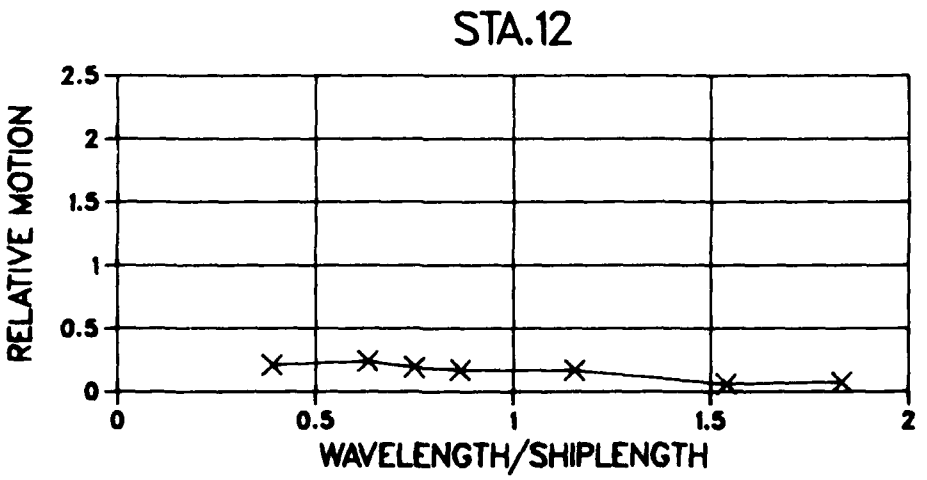

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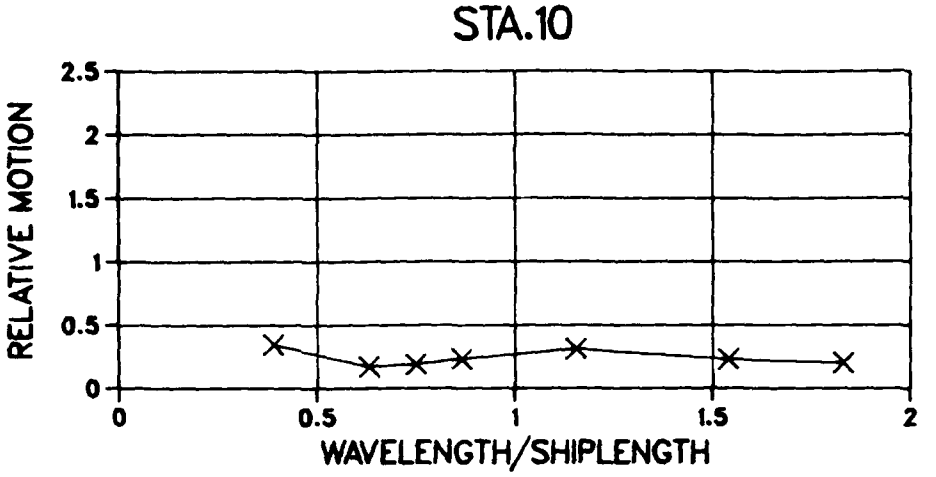

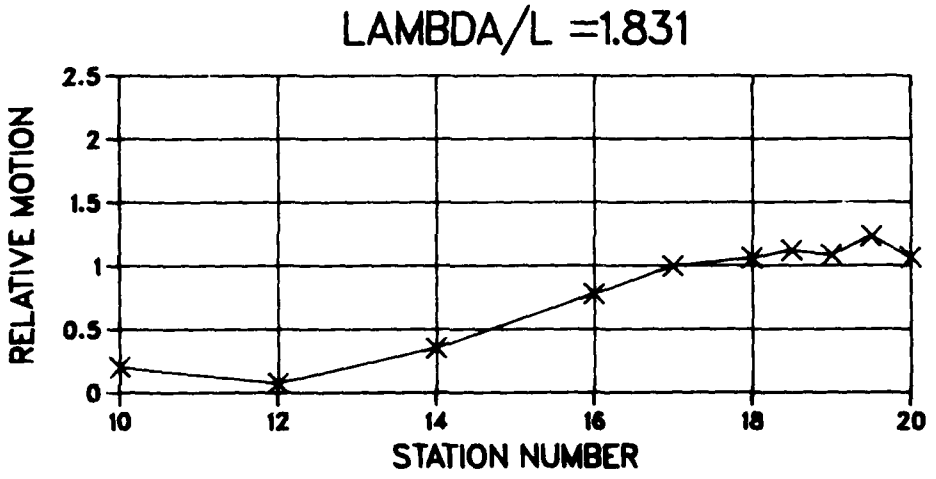

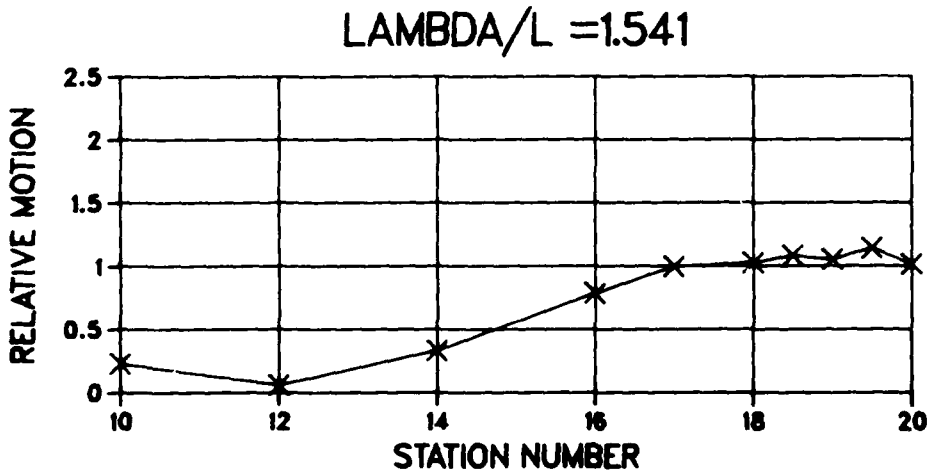

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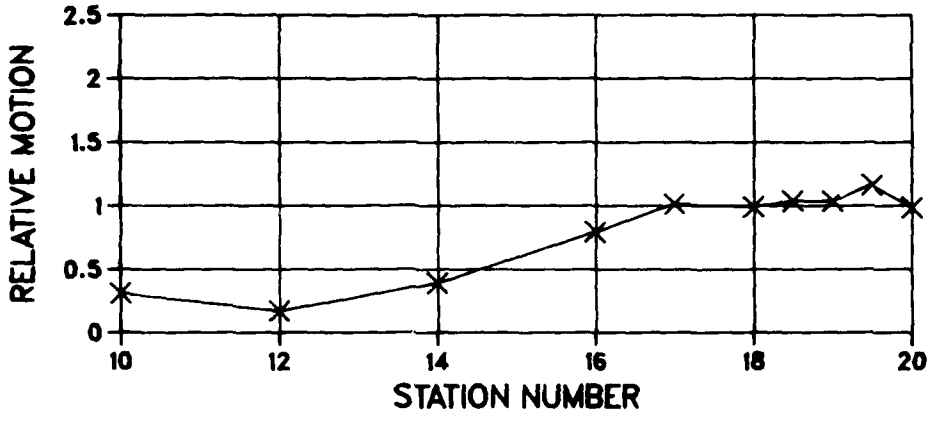

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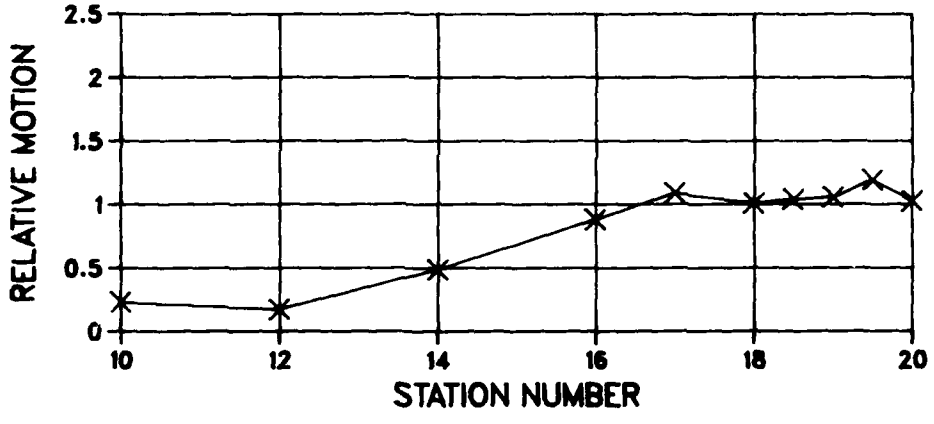

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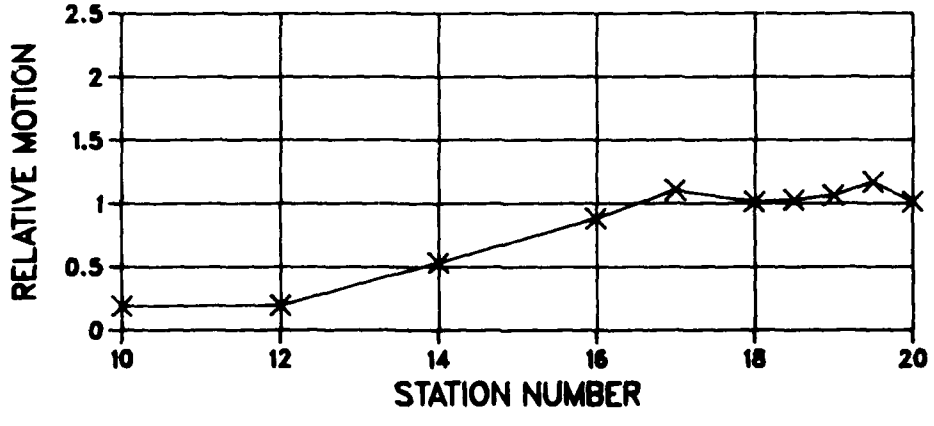

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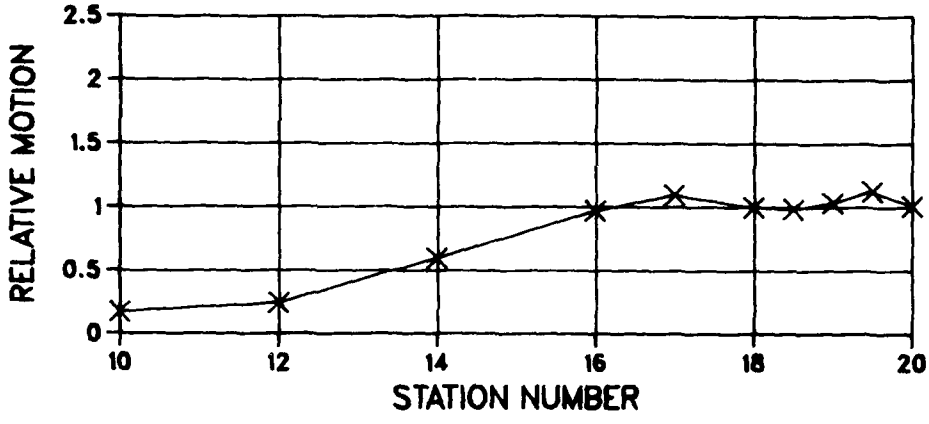

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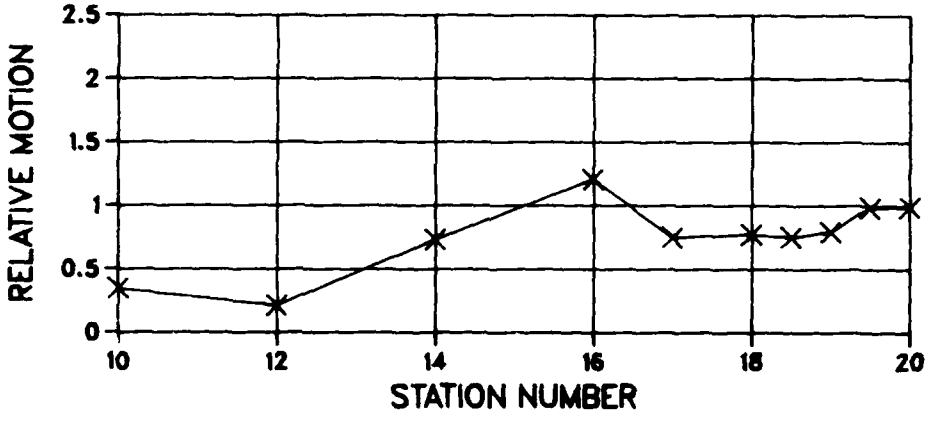
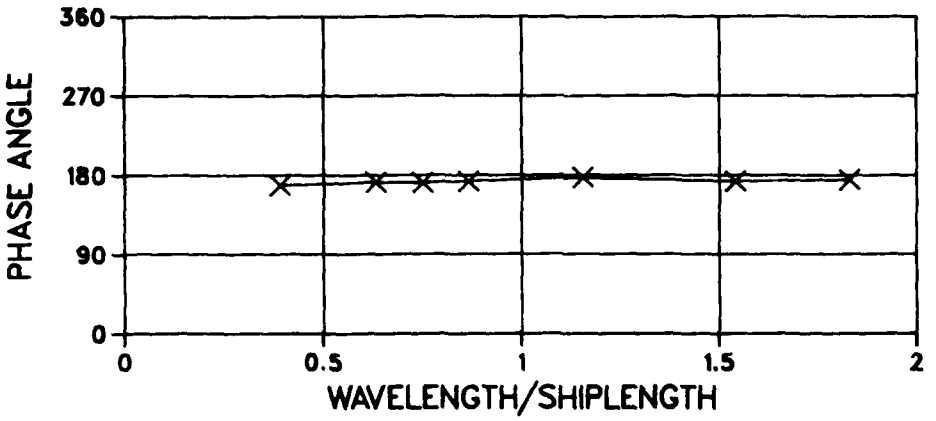


FORCED PITCH. FN=0.3

STA.20



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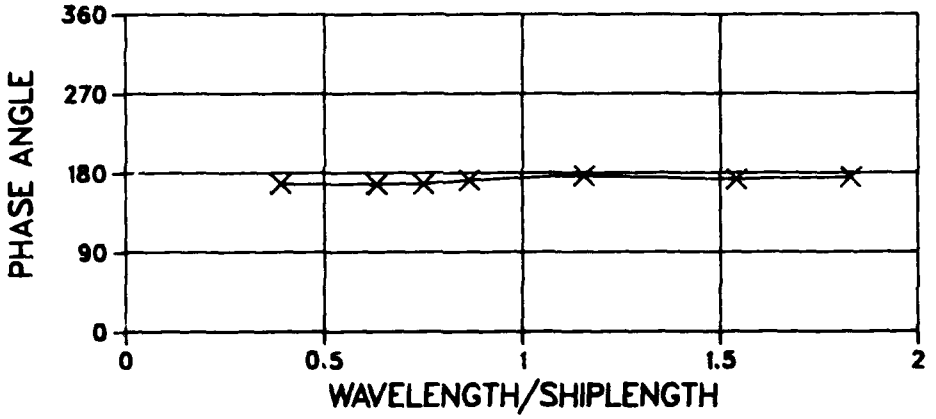

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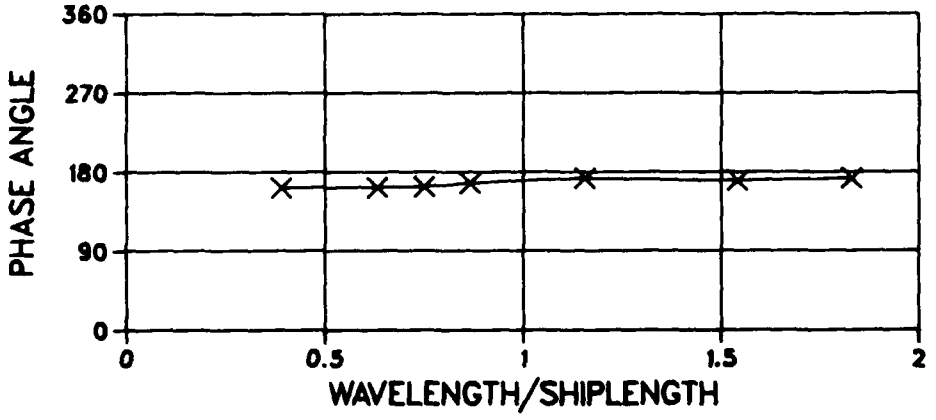

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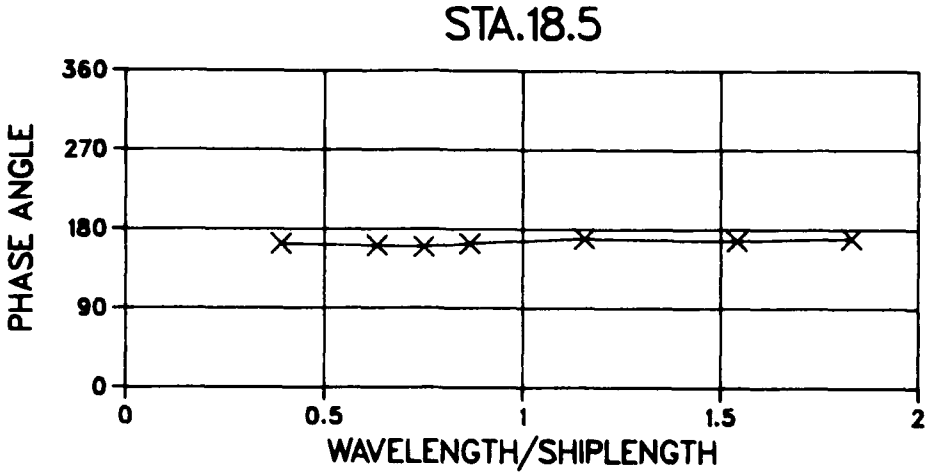
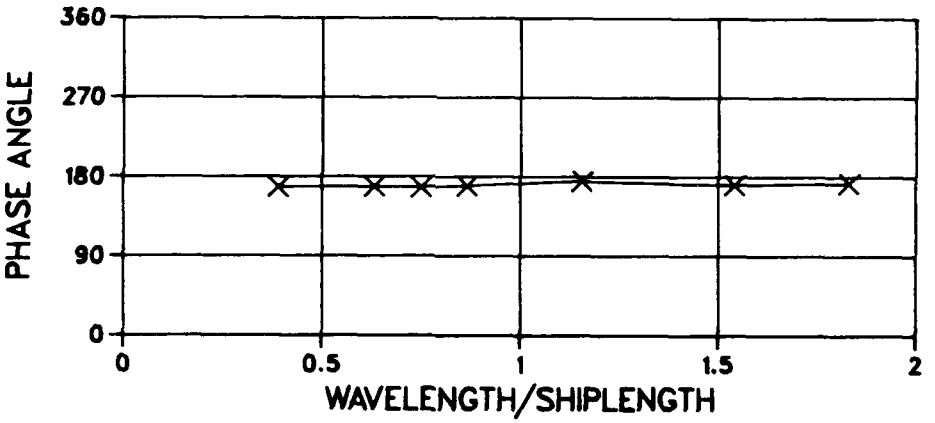
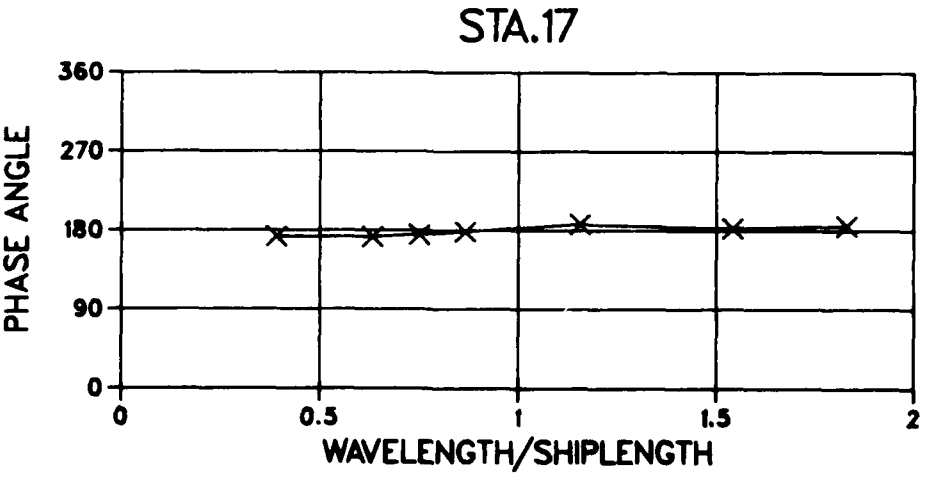
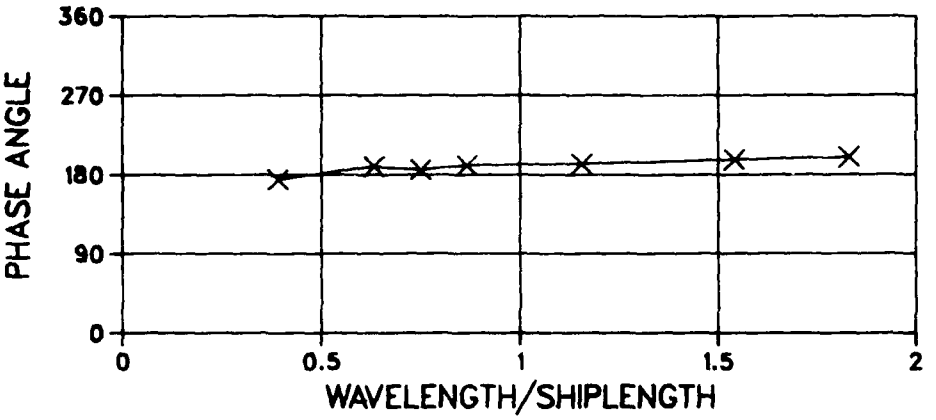






FORCED PITCH. FN=0.3

STA.16



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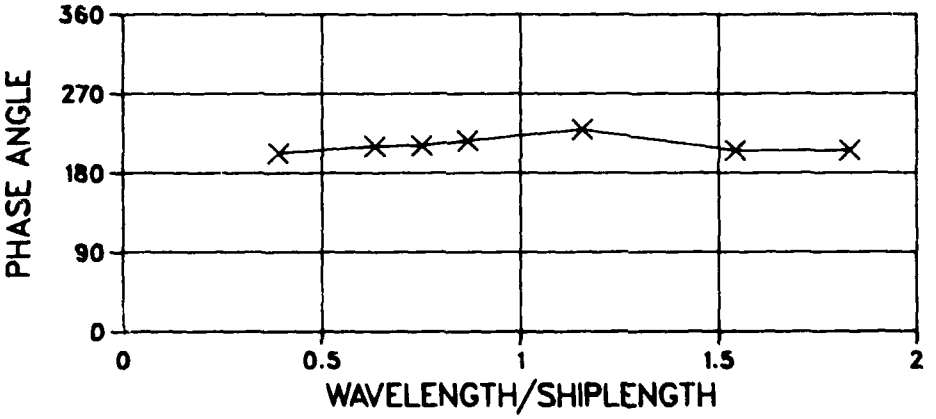

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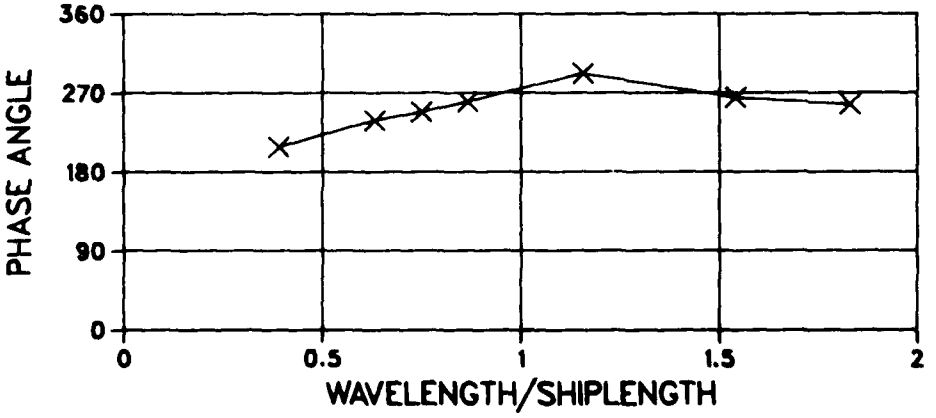

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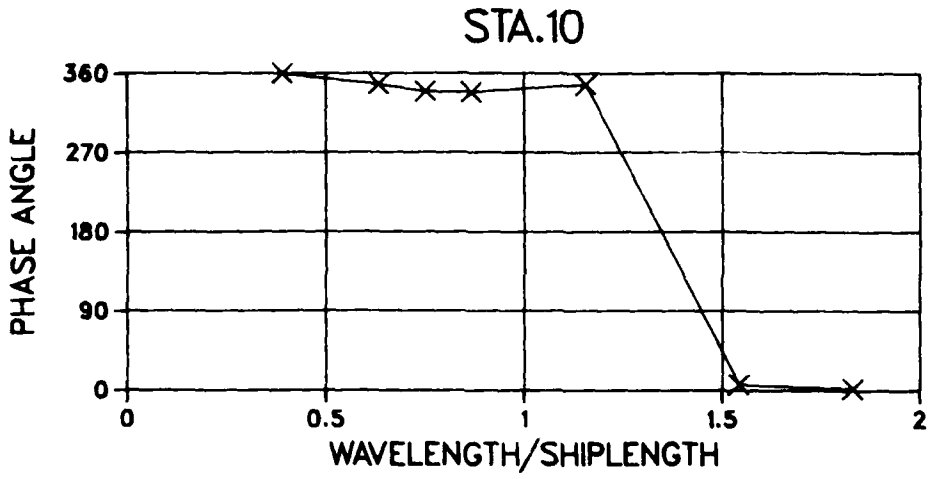

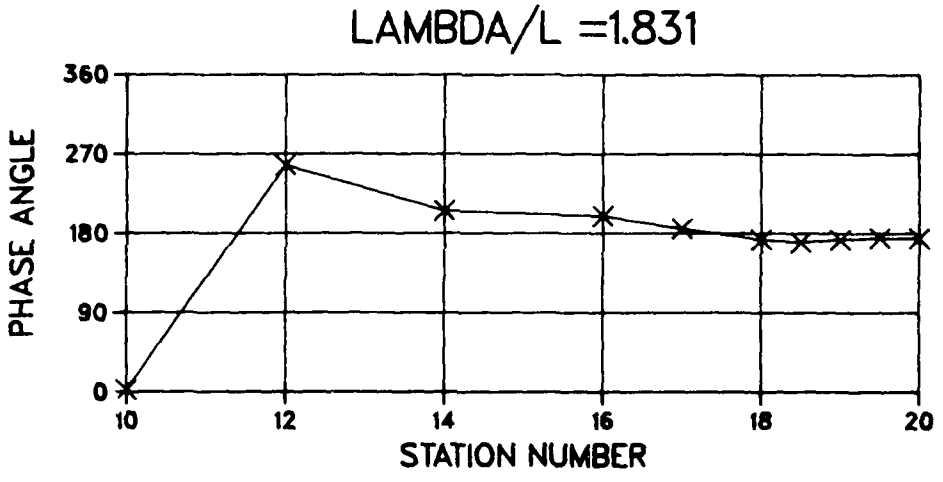

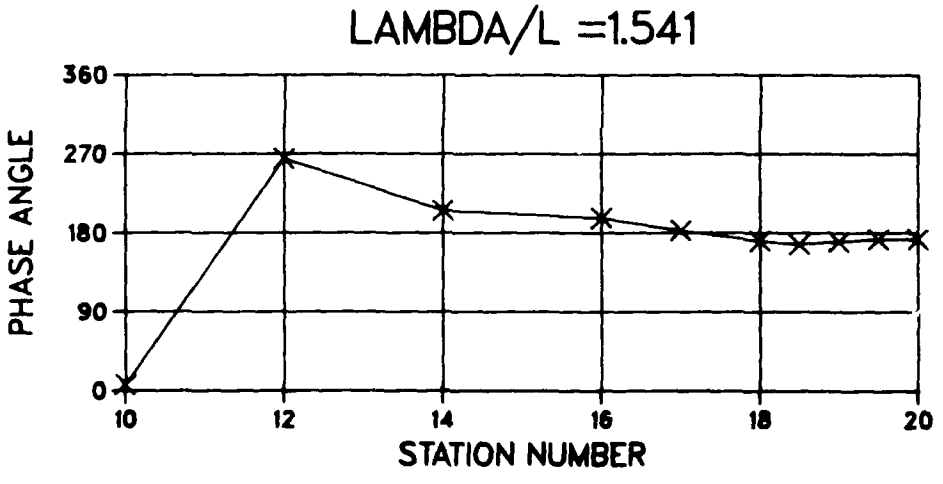

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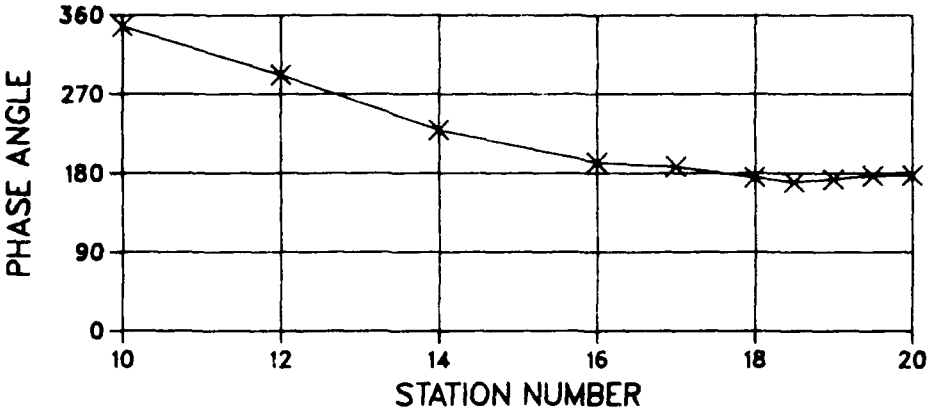

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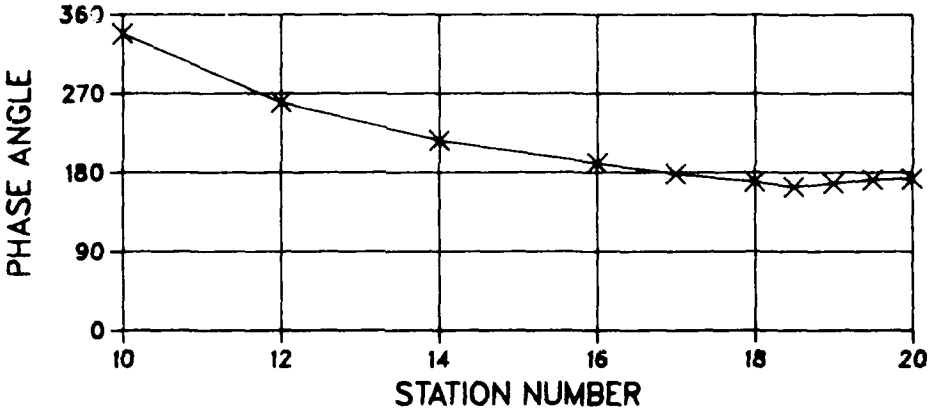

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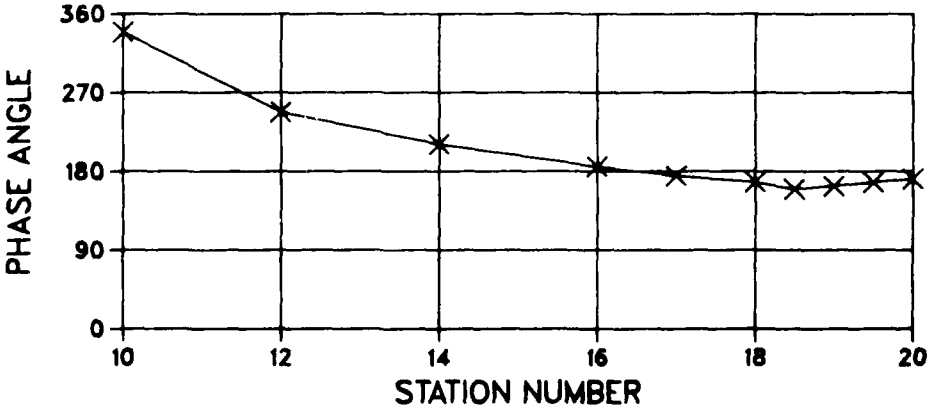

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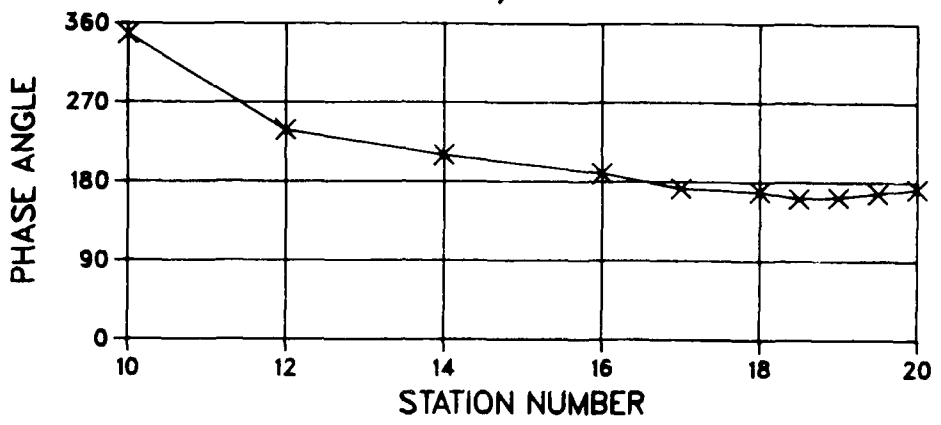

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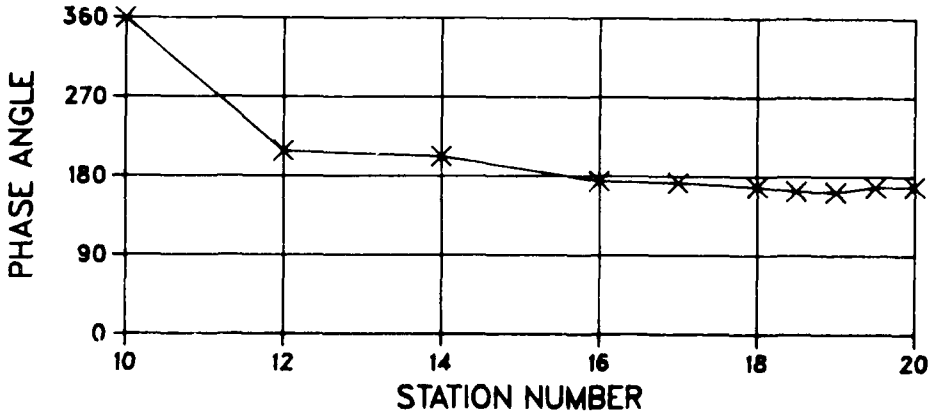

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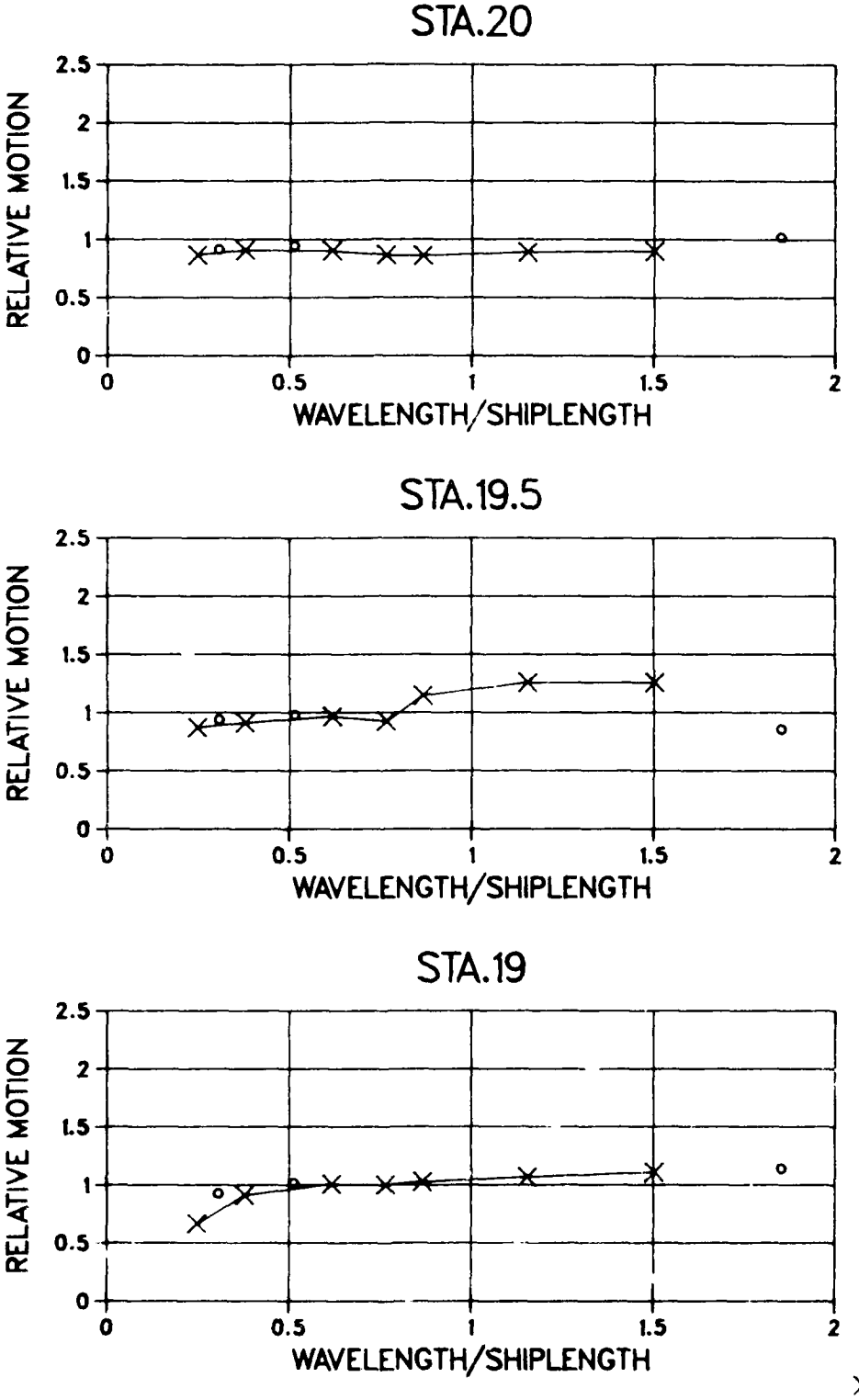
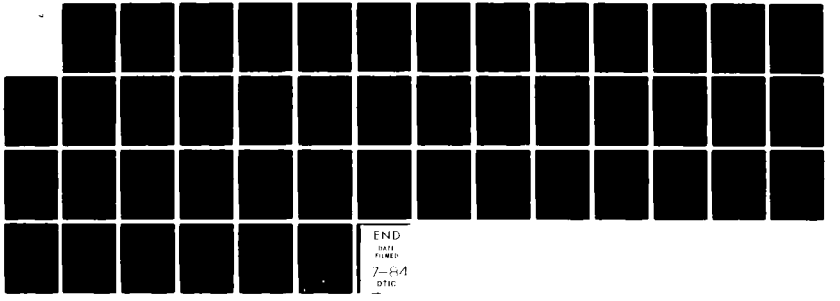
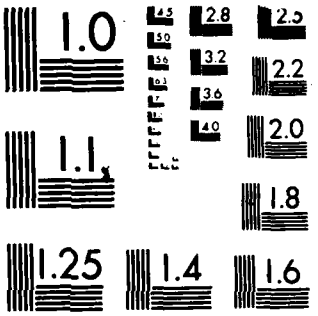


AD-A142 320 EXPERIMENTAL DETERMINATION OF THE WAVE ELEVATION NEXT TO A MODEL OF THE S..(U) MICHIGAN UNIV ANN ARBOR DEPT OF NAVAL ARCHITECTURE AND MARINE.. A W TROESCH ET AL.

2/2

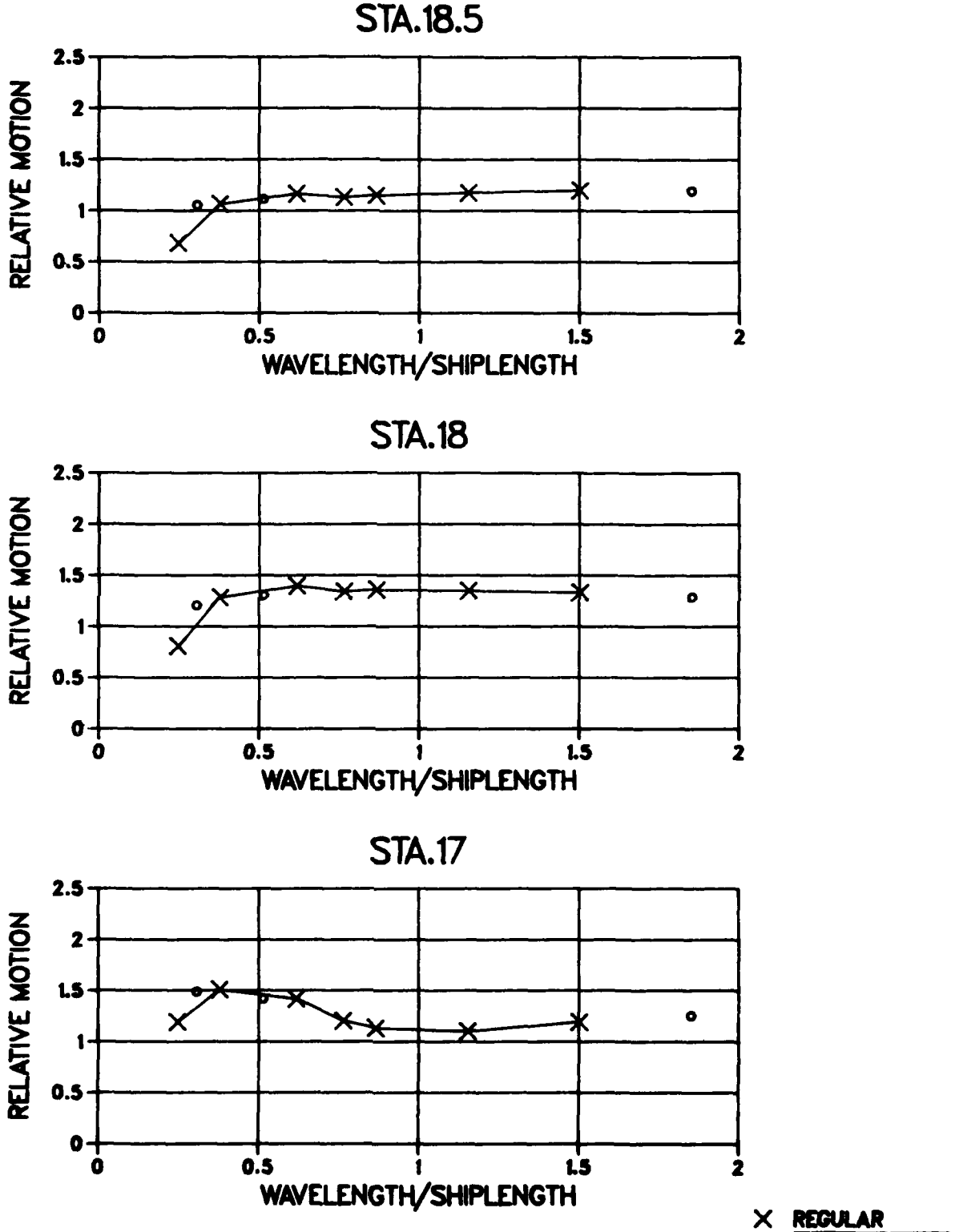
UNCLASSIFIED 25 MAR 84 N00014-83-K-0305 F/G 12/1 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

FORCED HEAVE. FN=0.2



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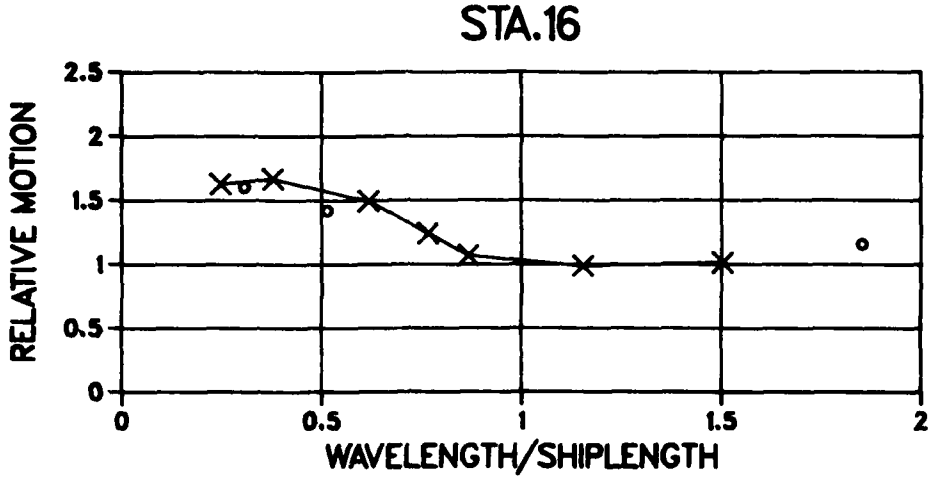
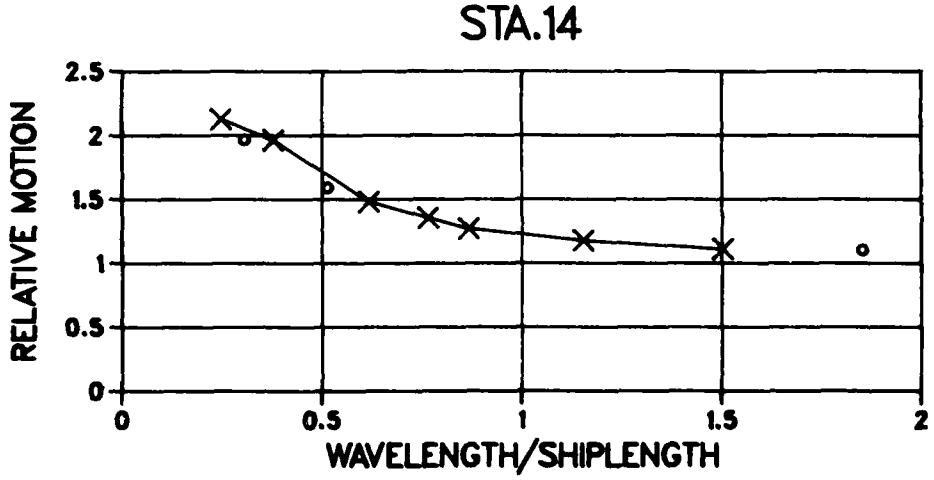
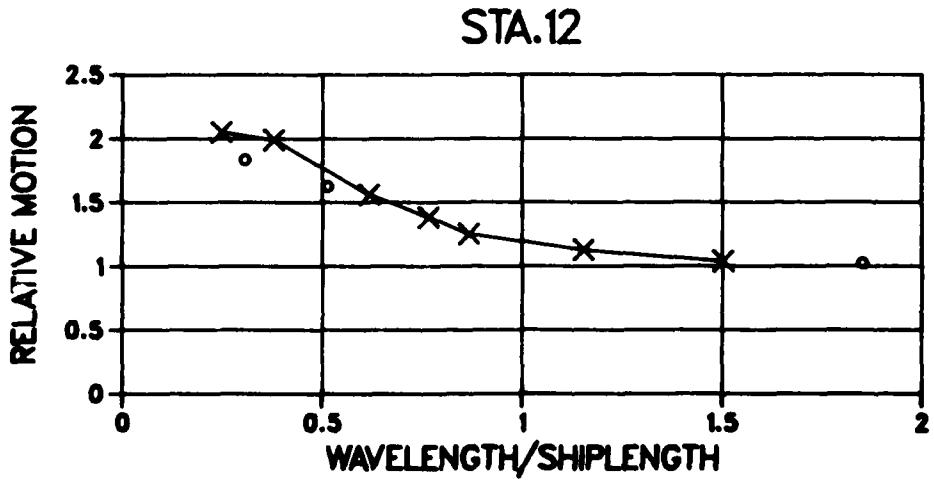


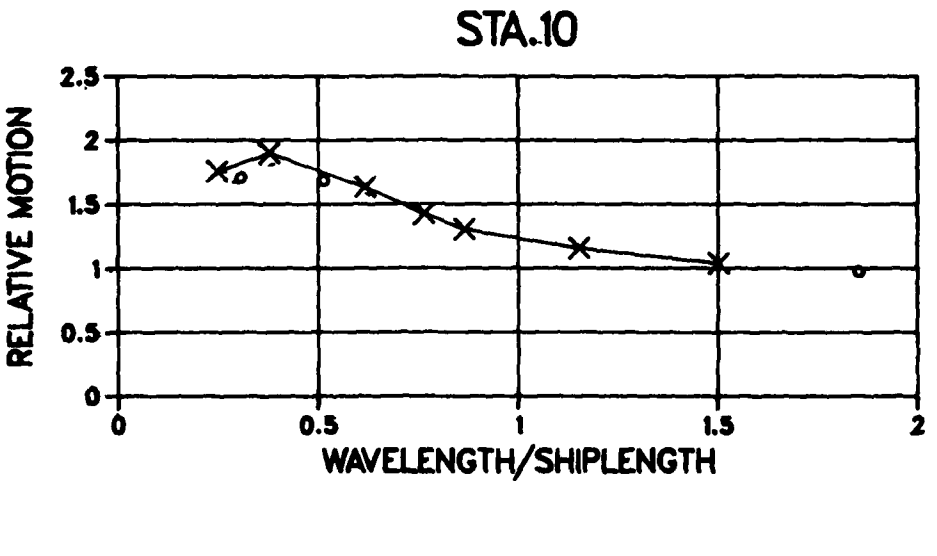




× REGULAR

o LINEARITY TEST

FORCED HEAVE. FN=0.2



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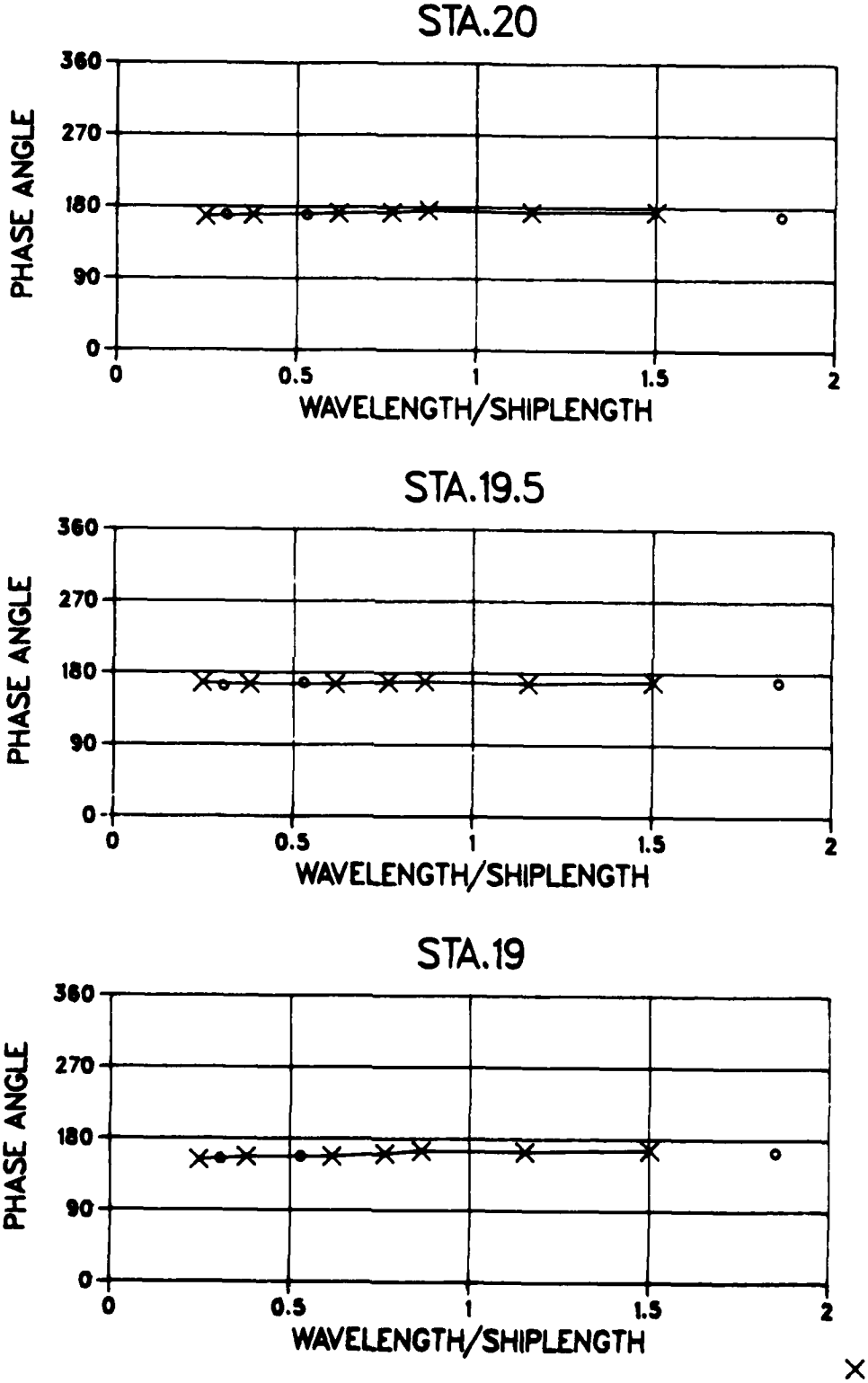

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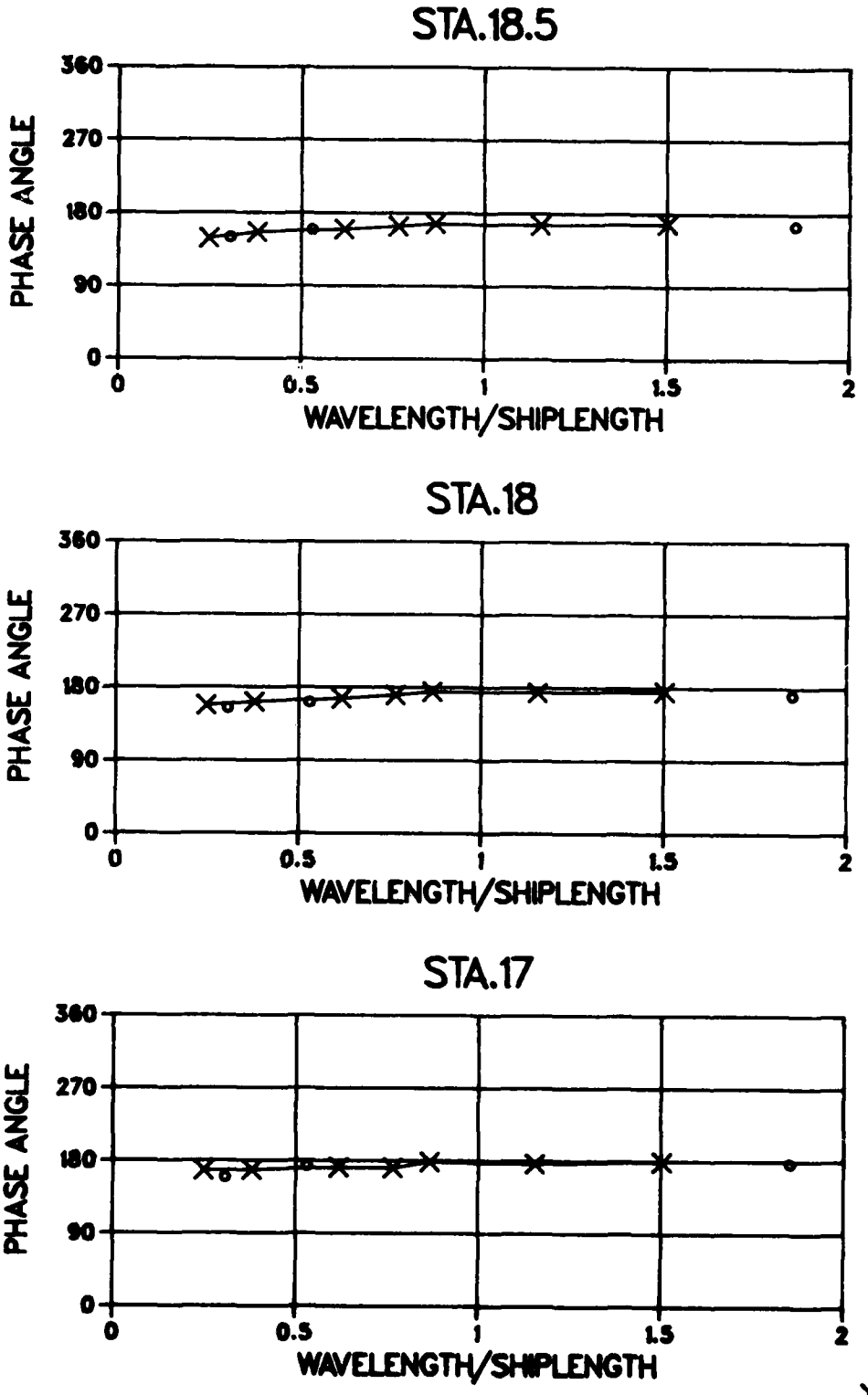

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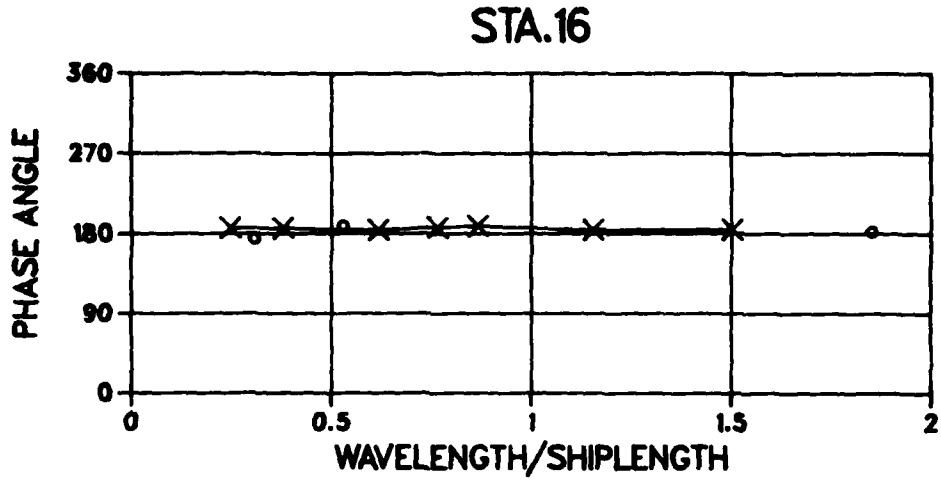
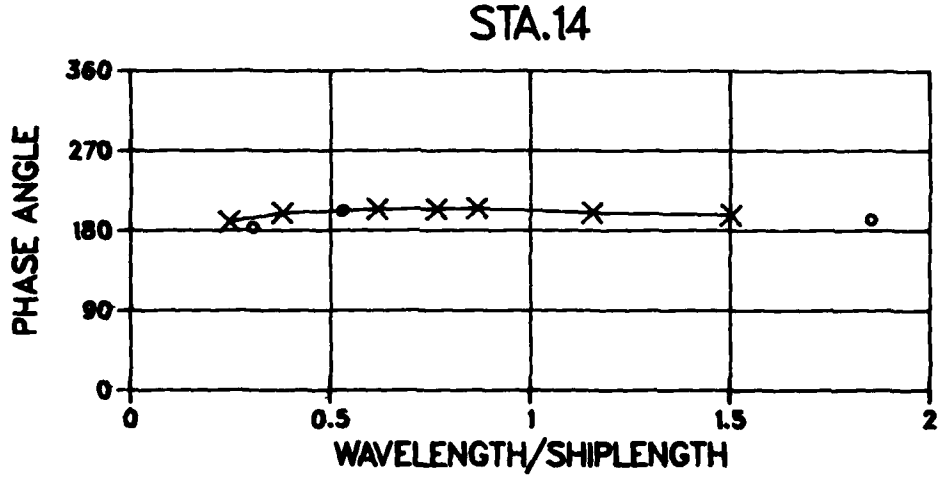
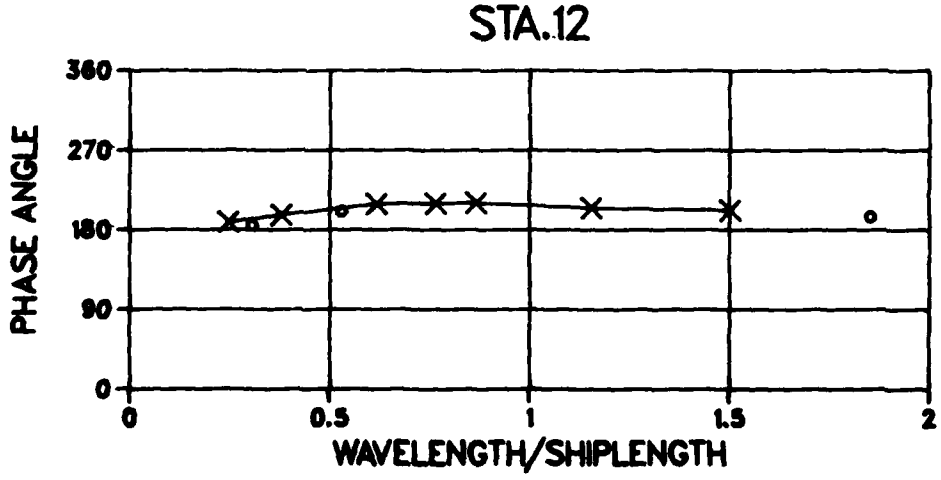


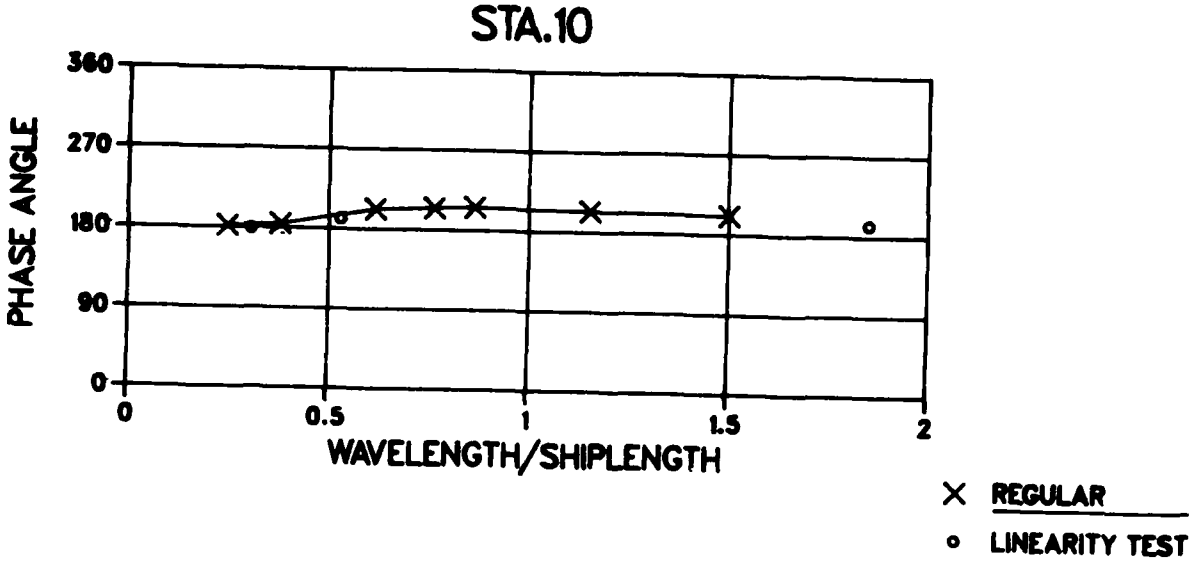




× REGULAR

o LINEARITY TEST

FORCED HEAVE. FN=0.2



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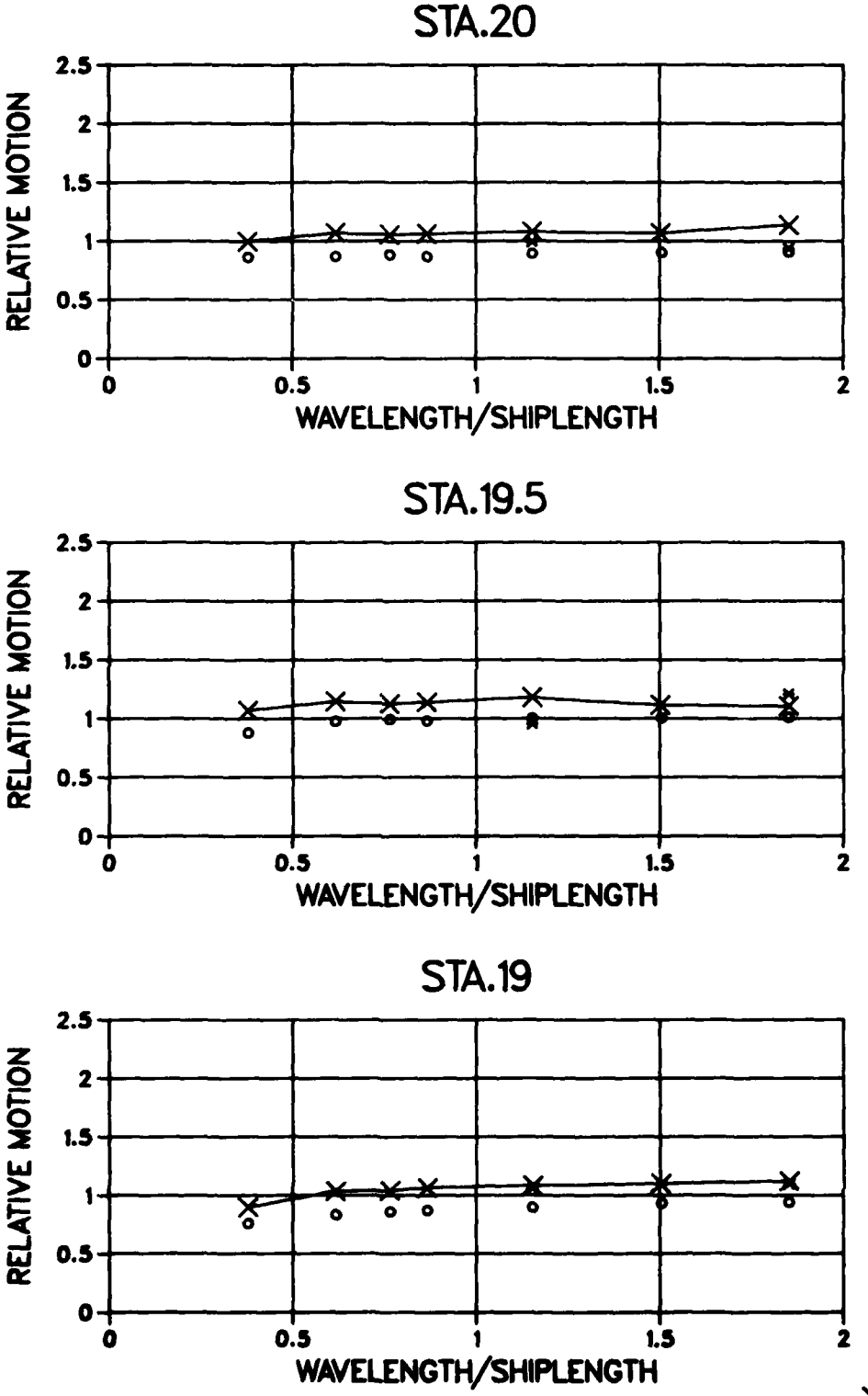

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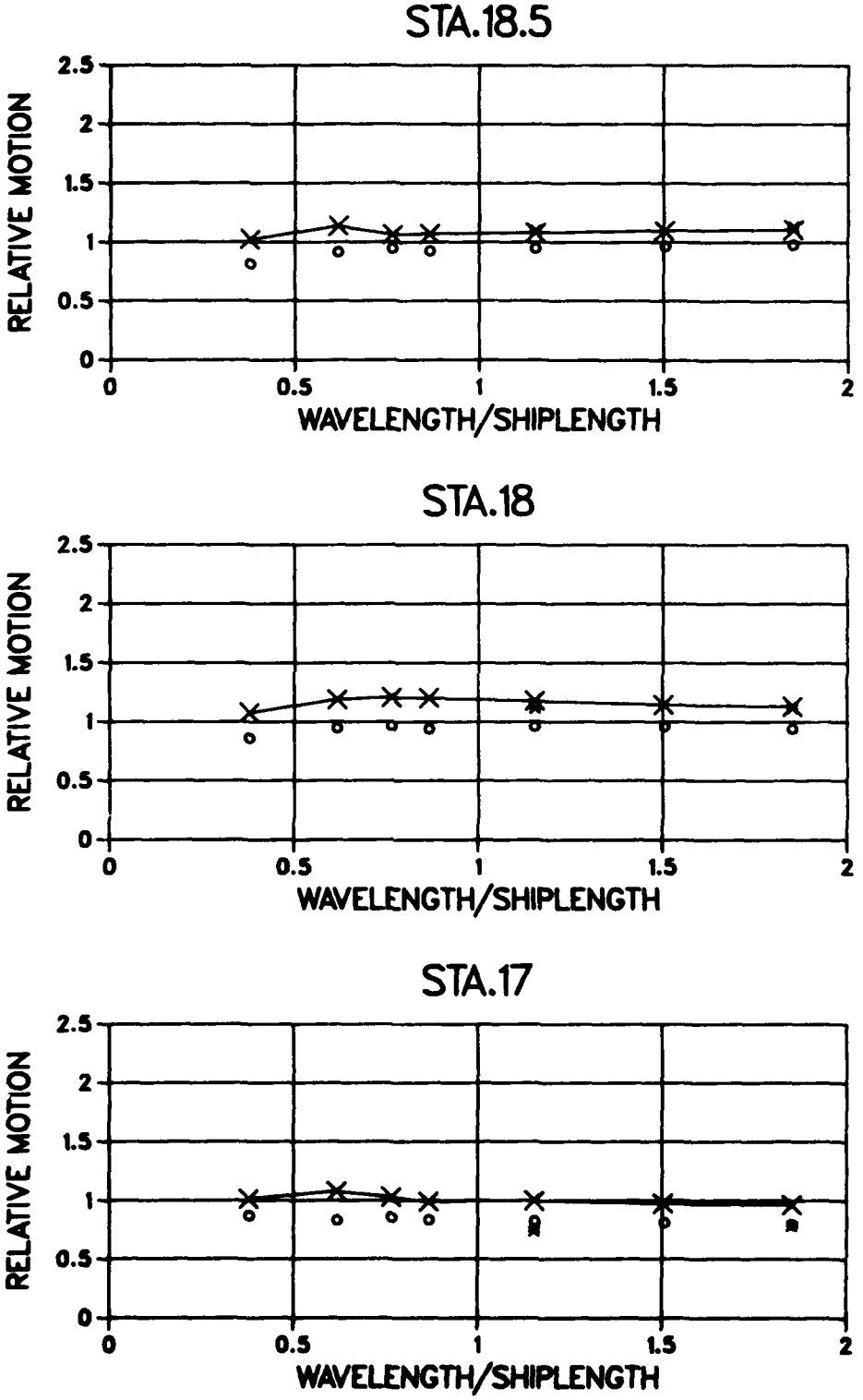

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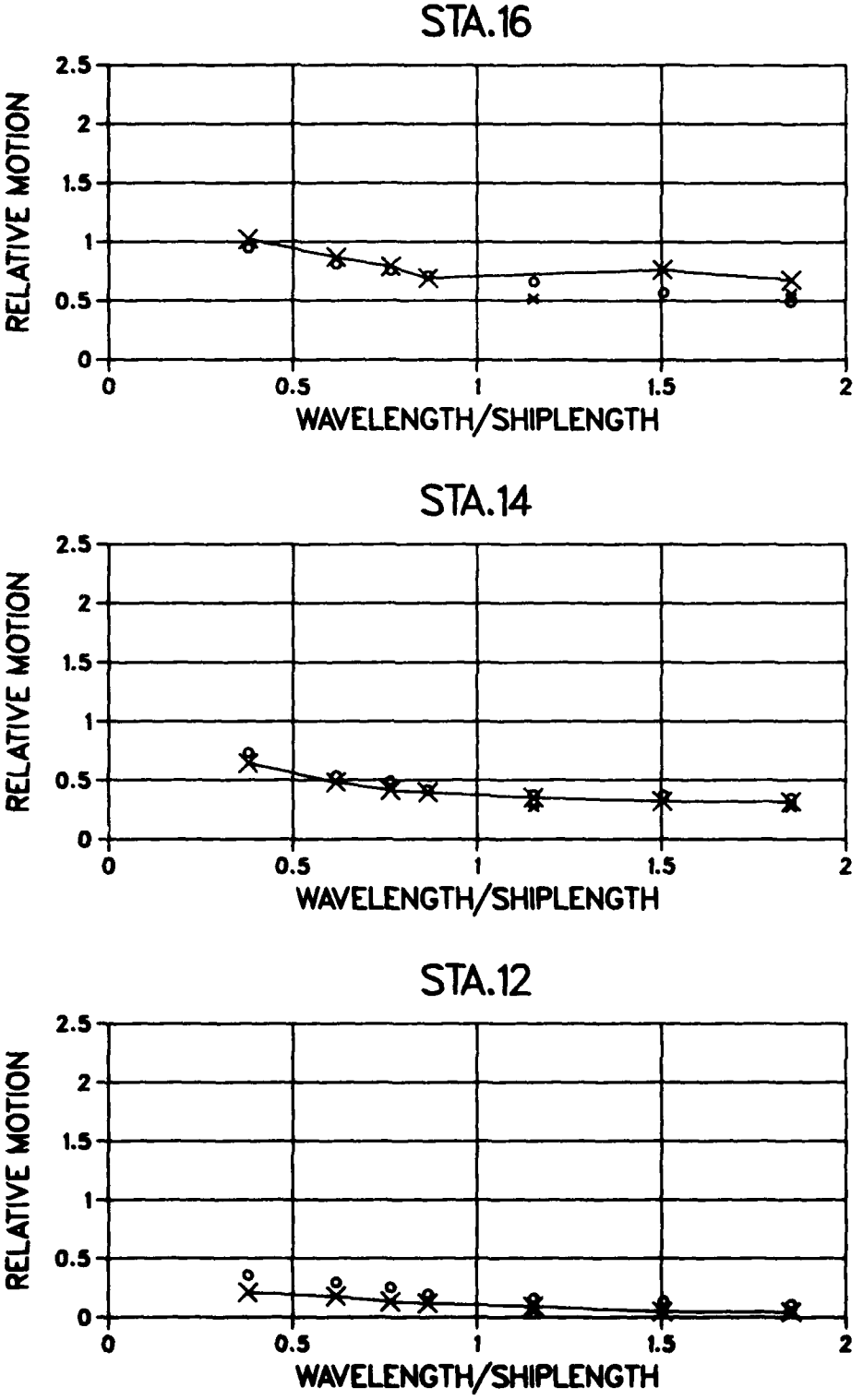

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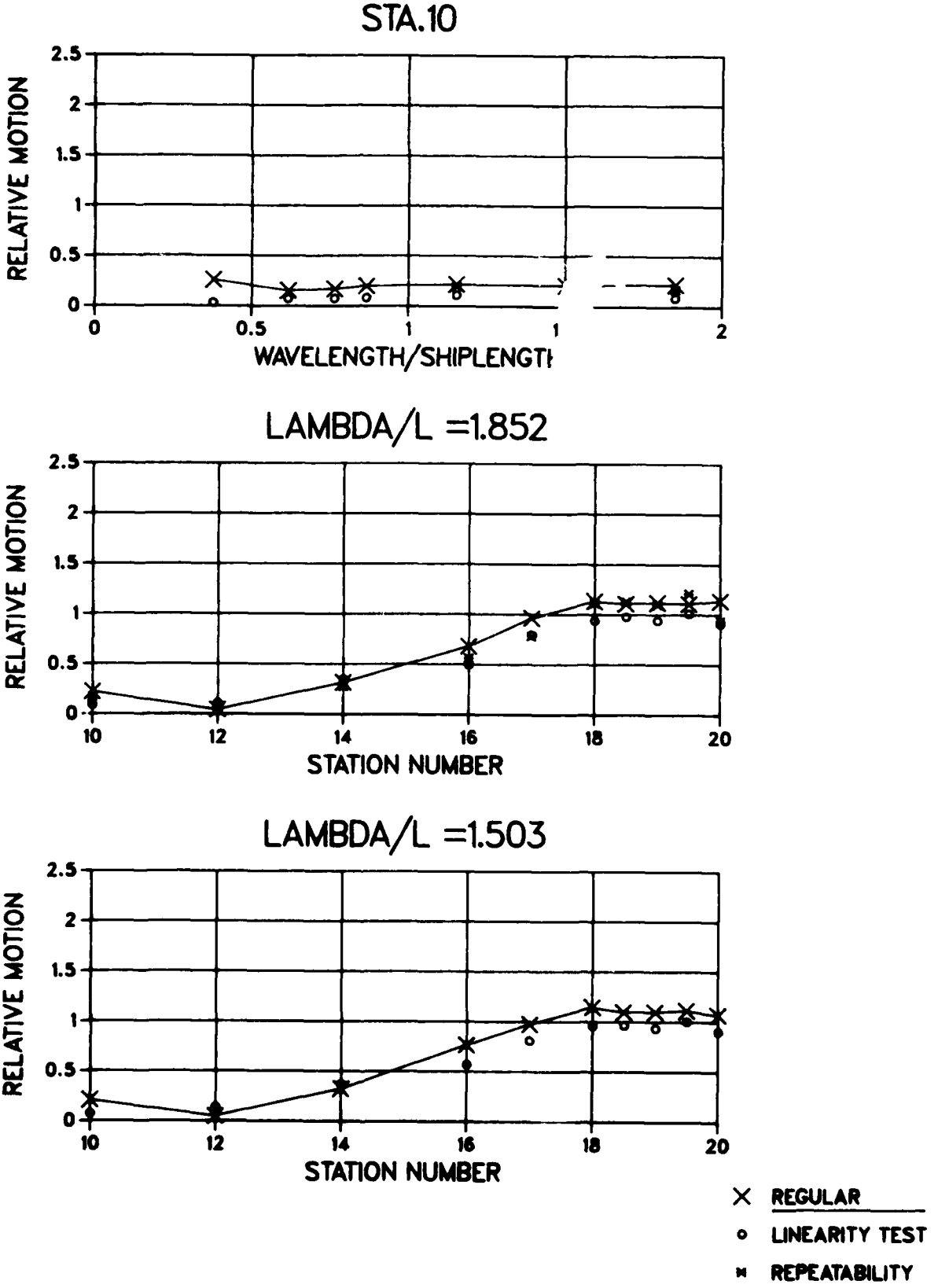

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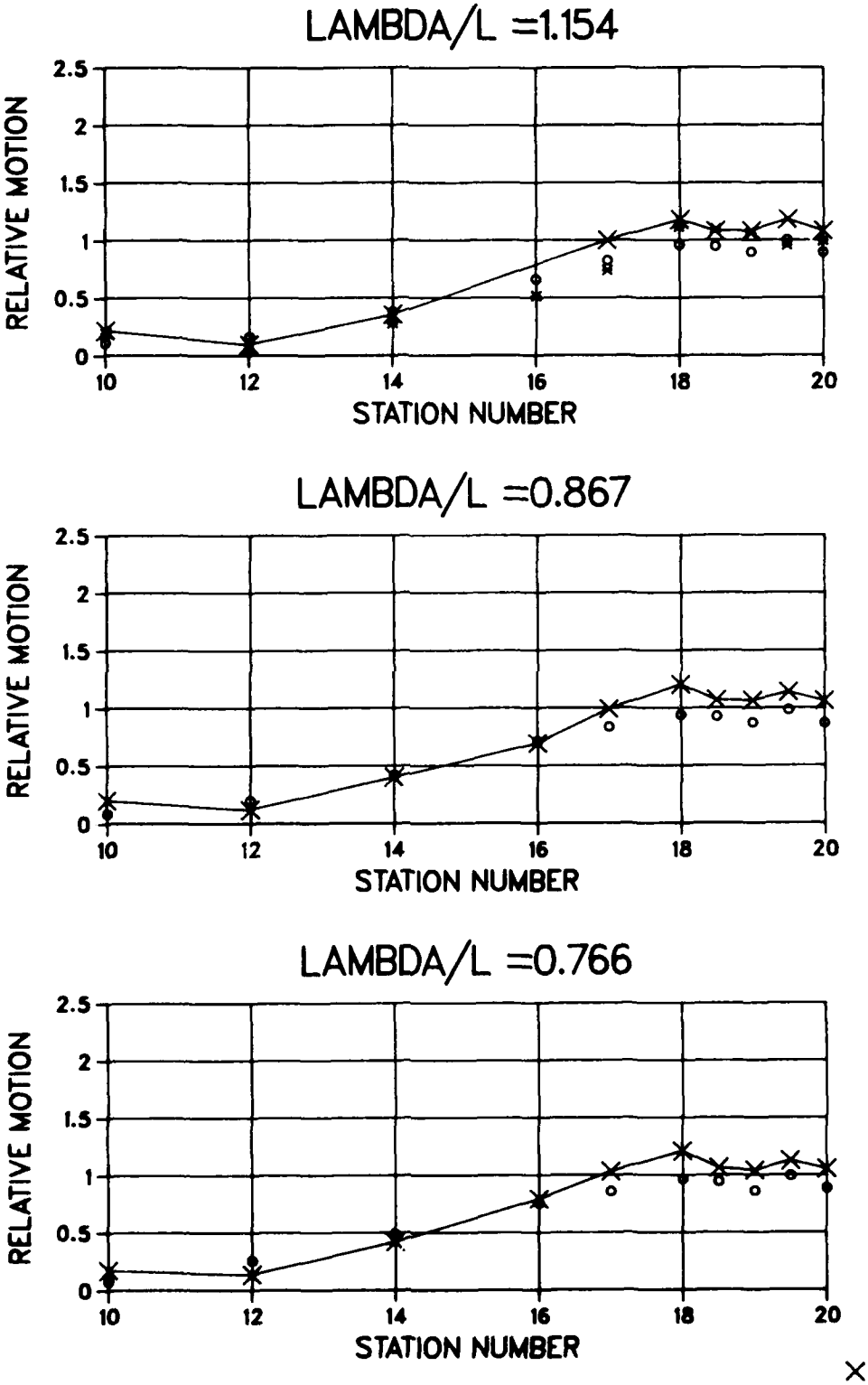

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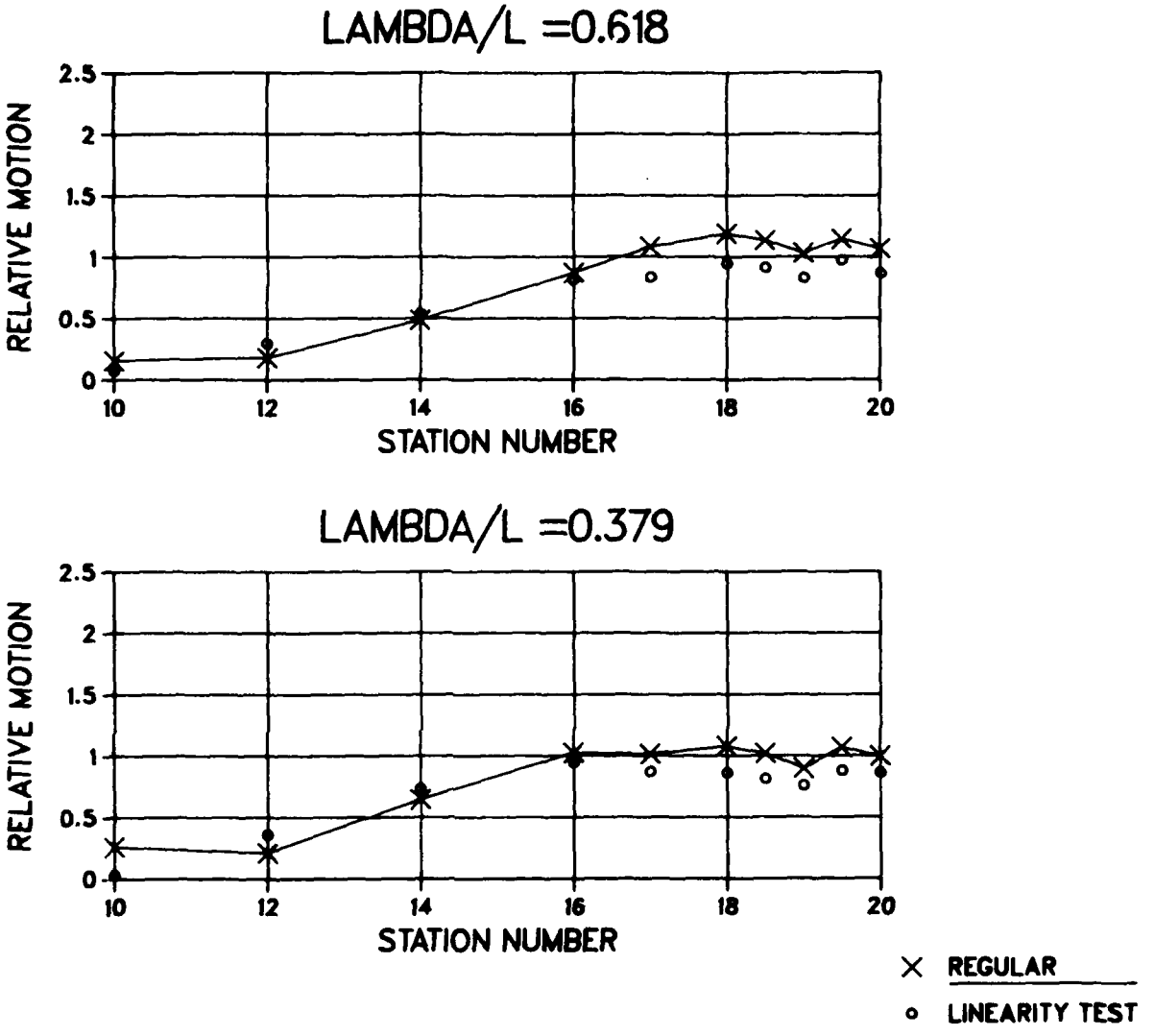

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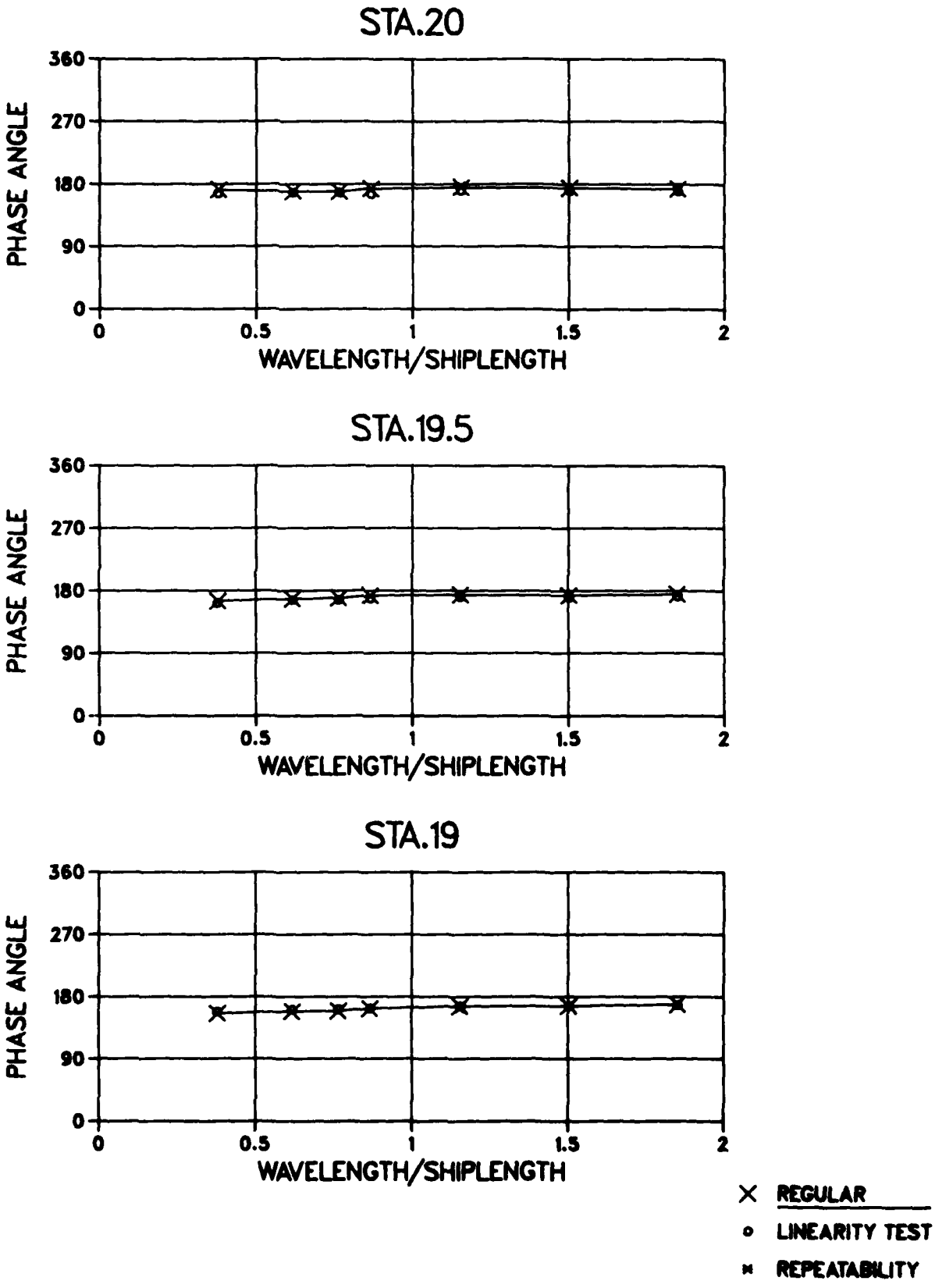

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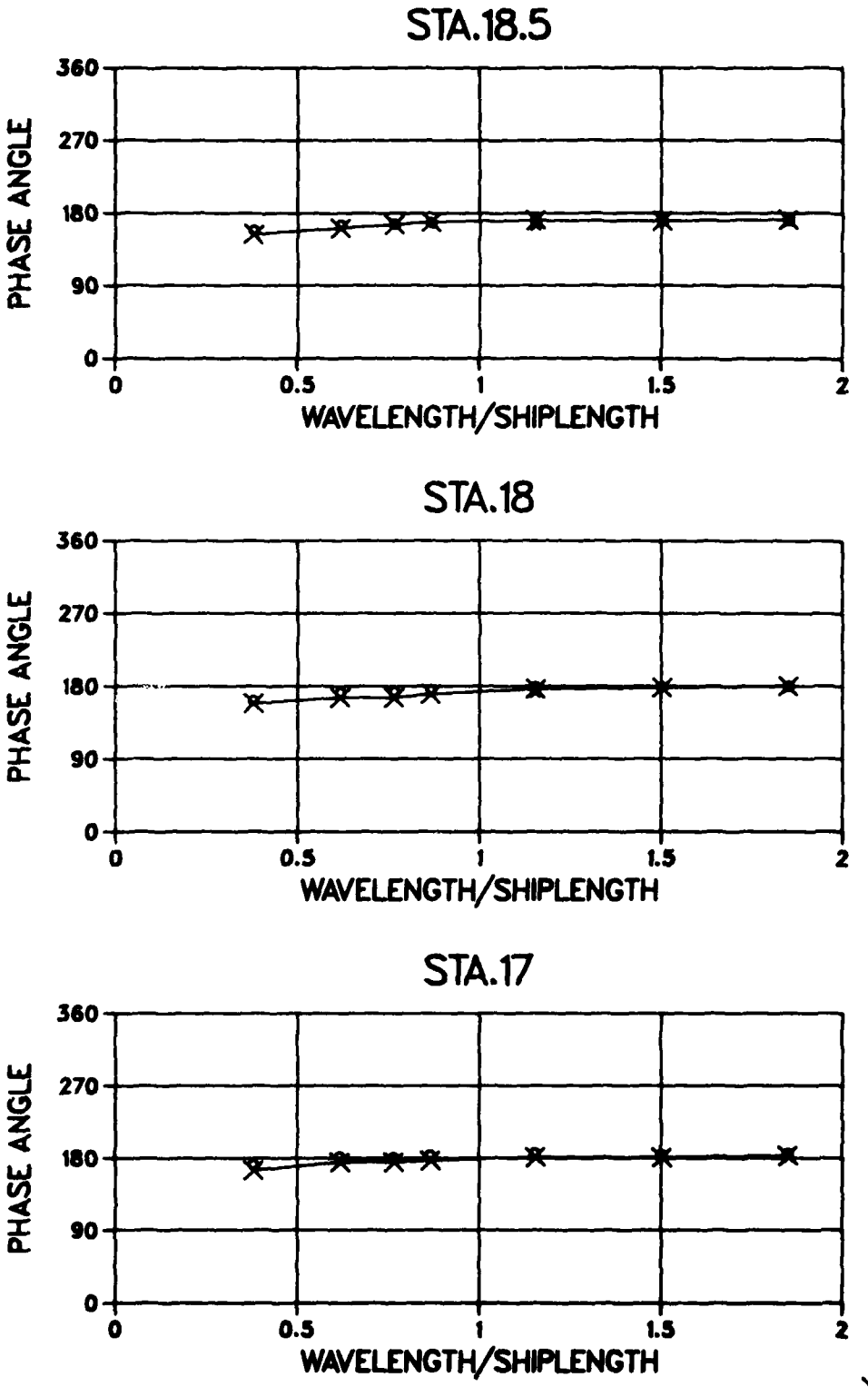

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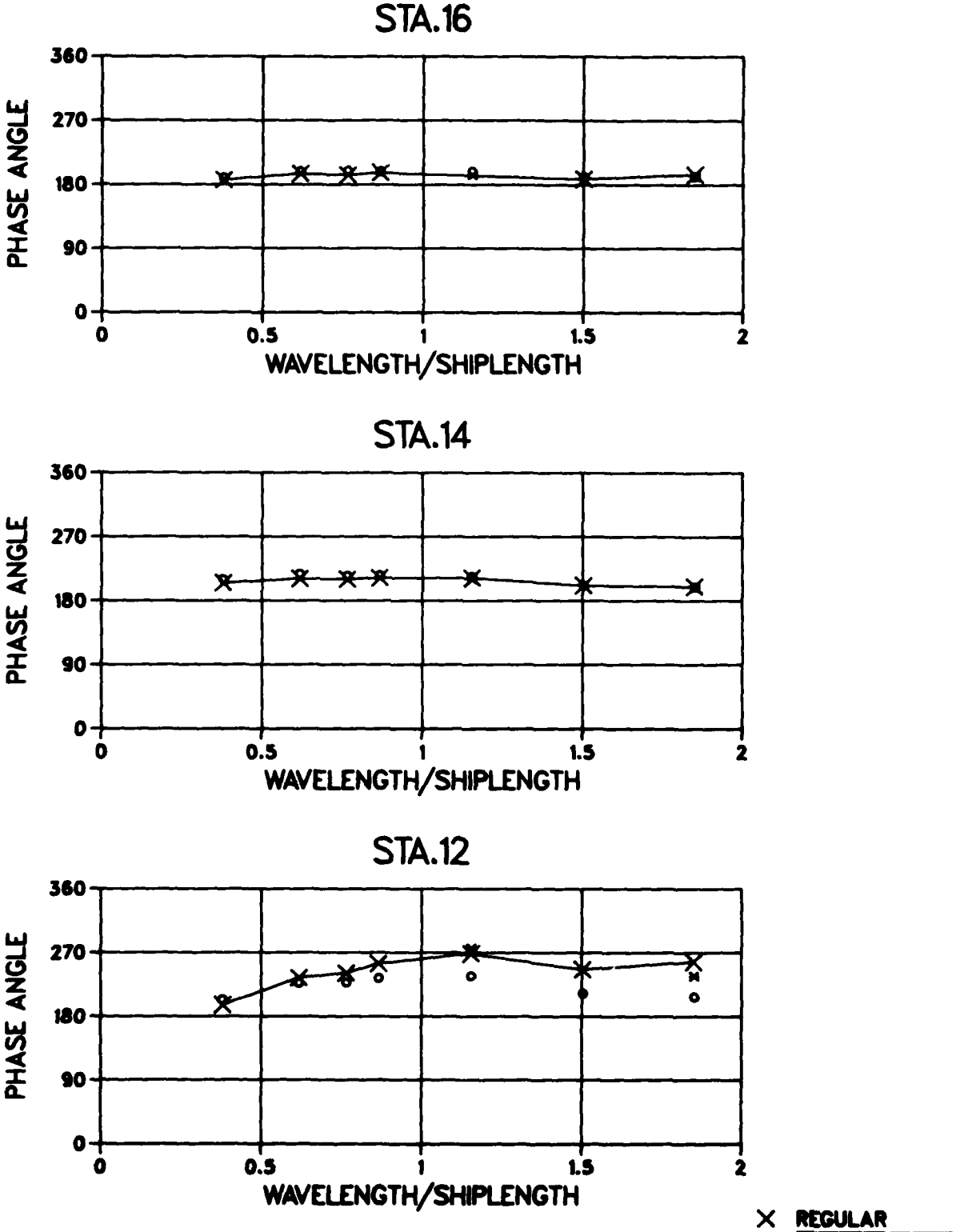

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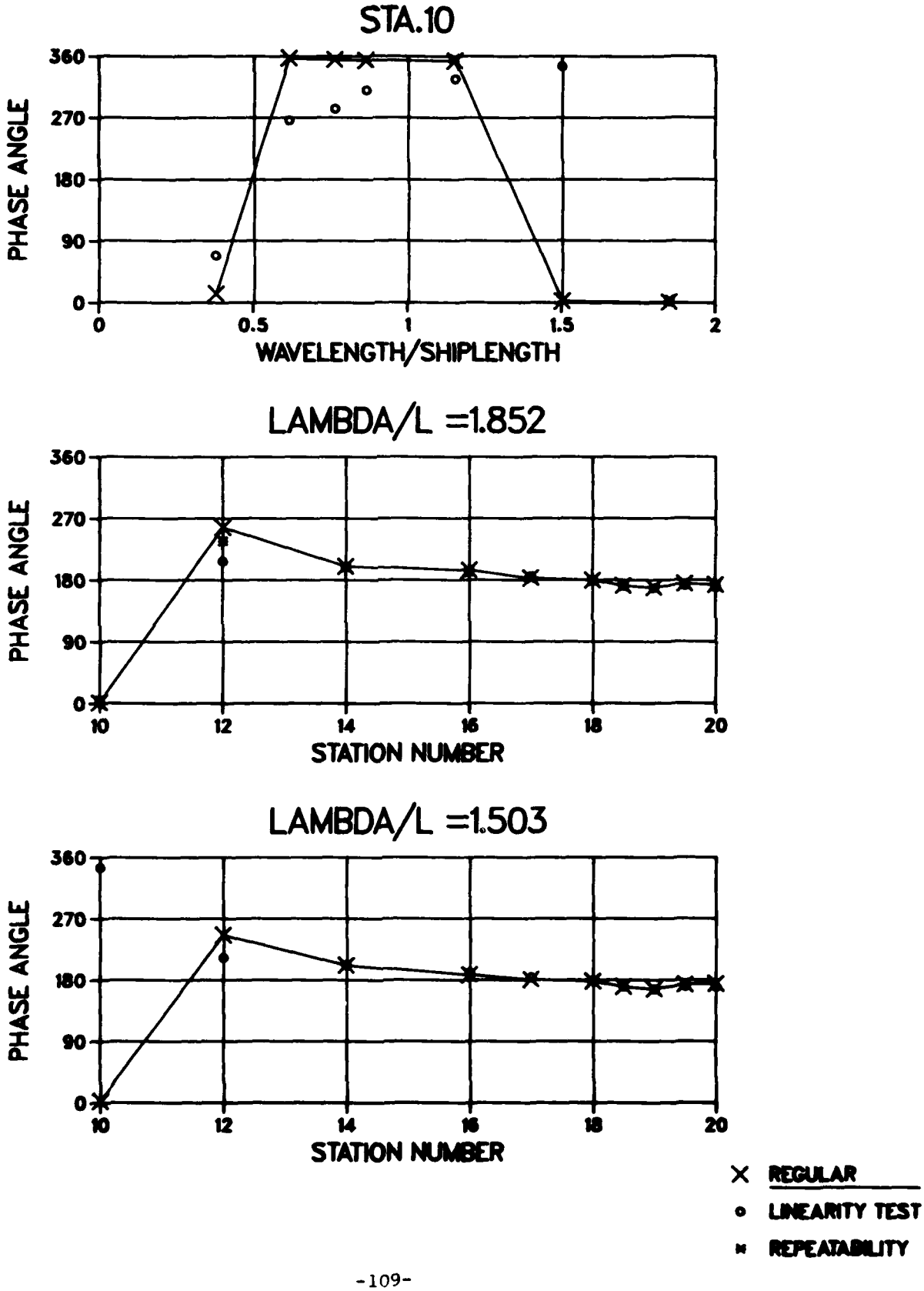

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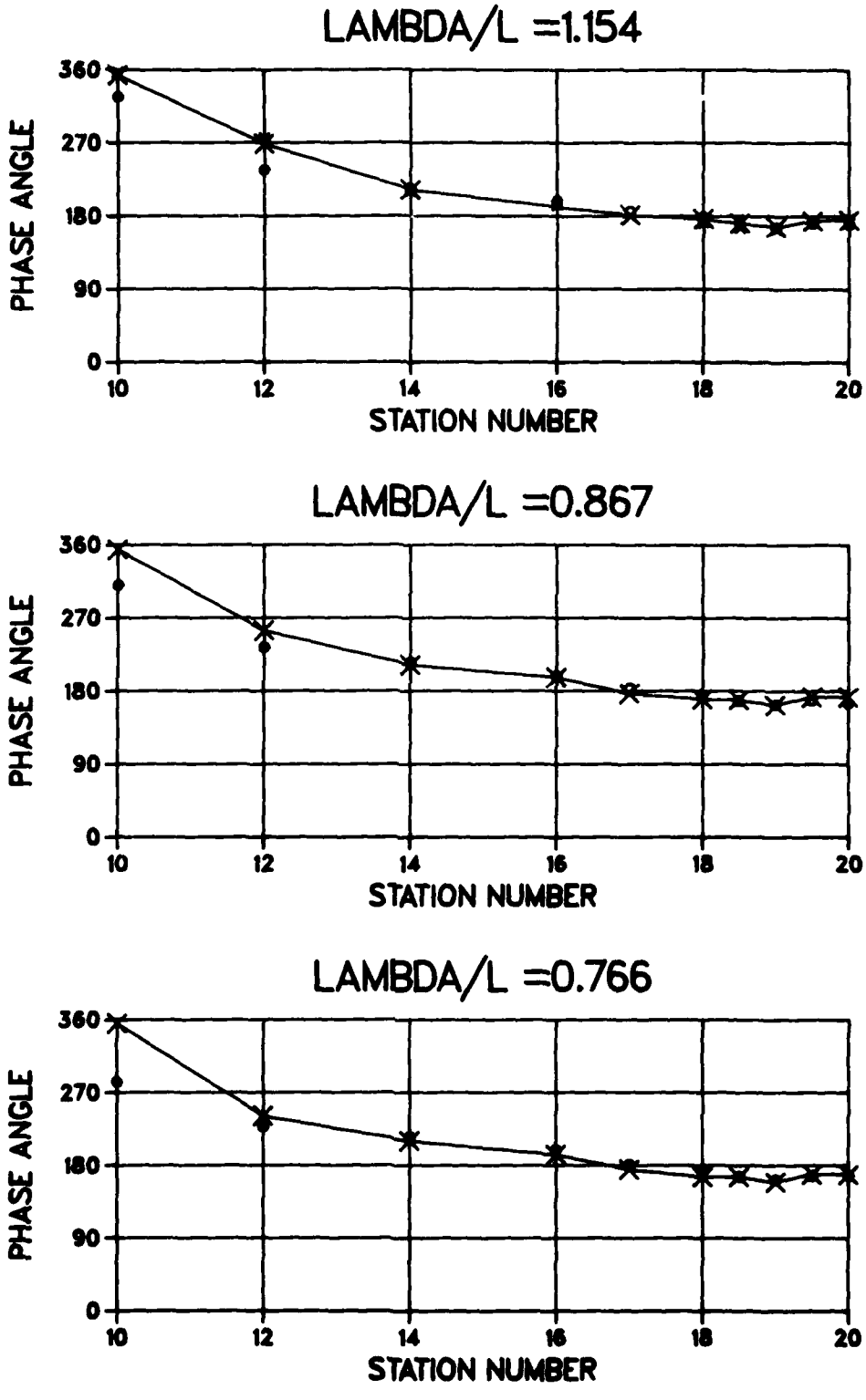

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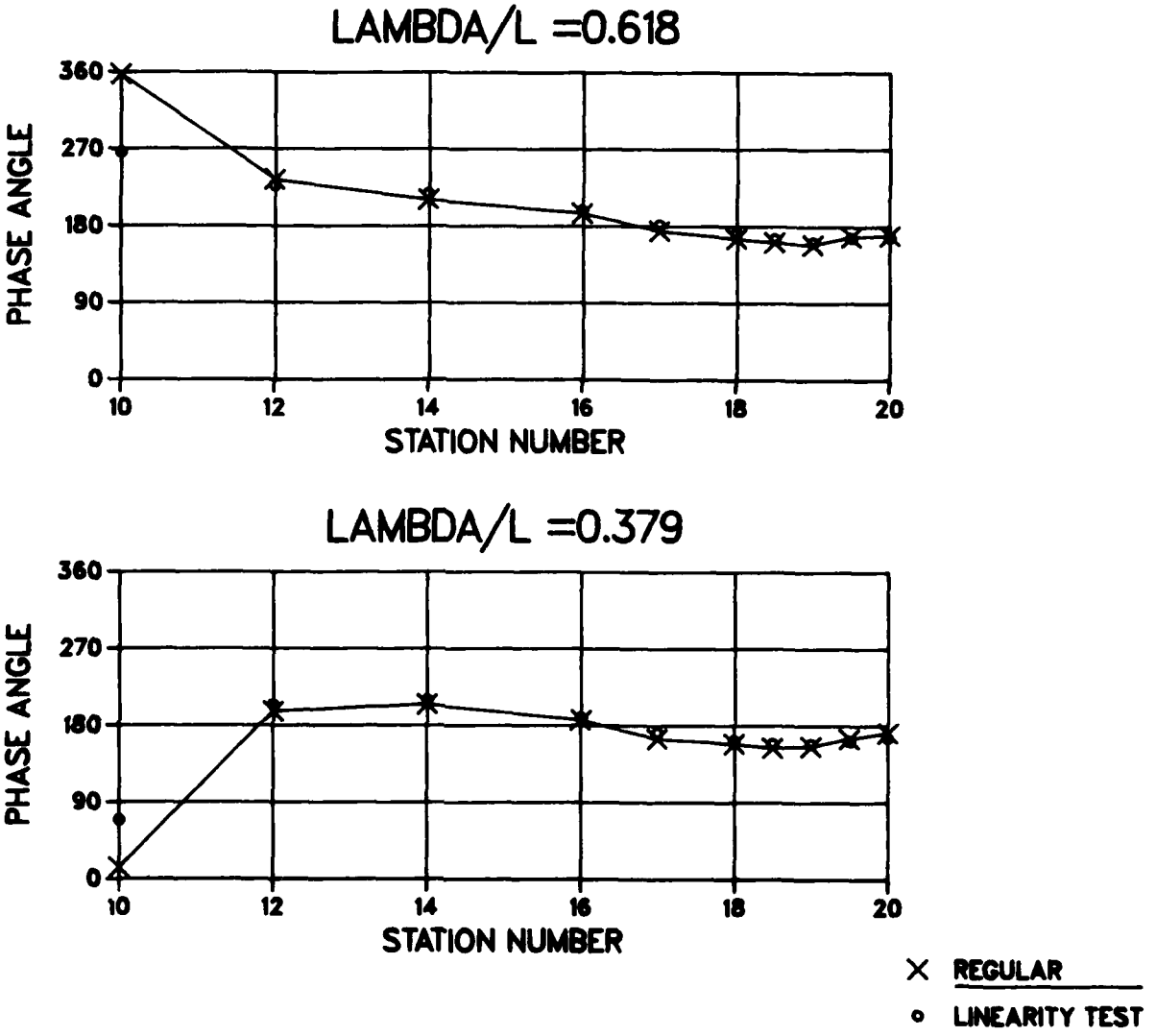
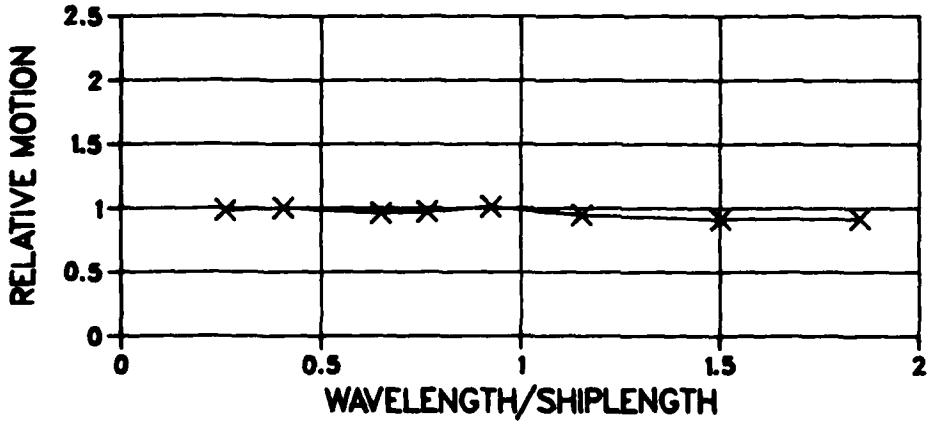


DIFFRACTION. FN=0.2

STA.20



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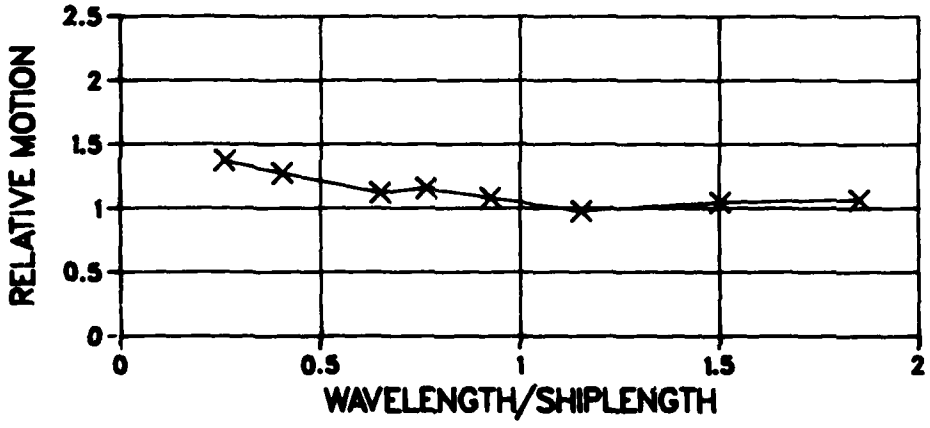
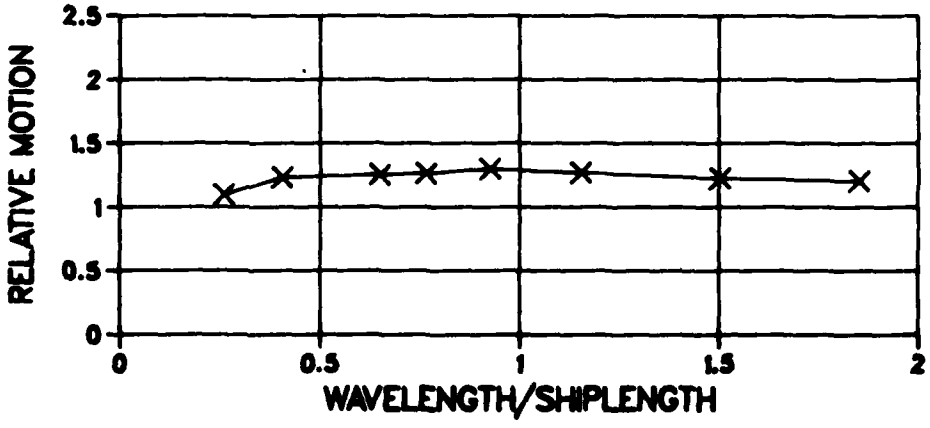
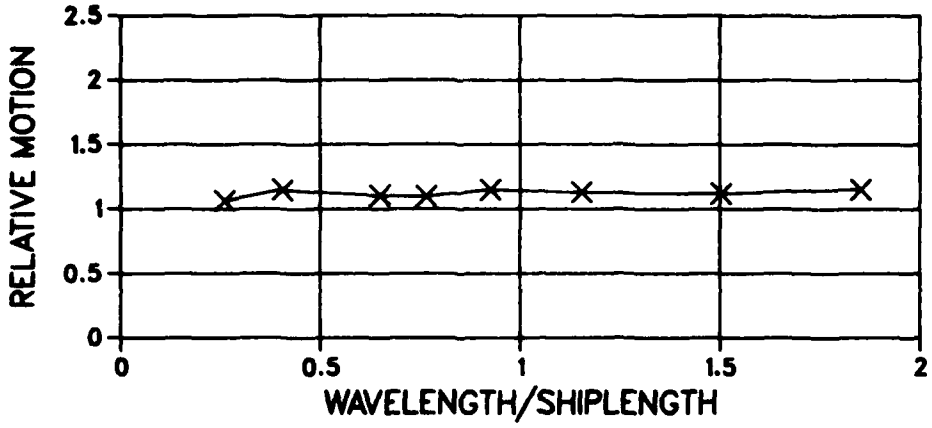


STA.19



DIFFRACTION. FN=0.2

STA.18.5



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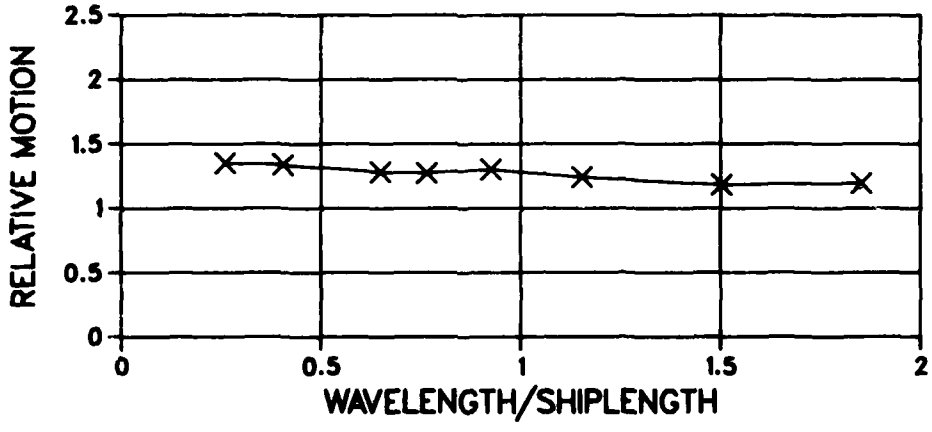

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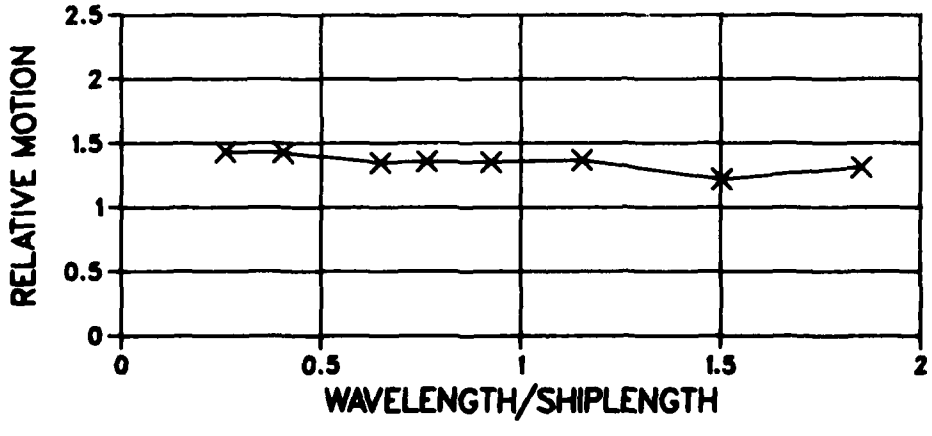

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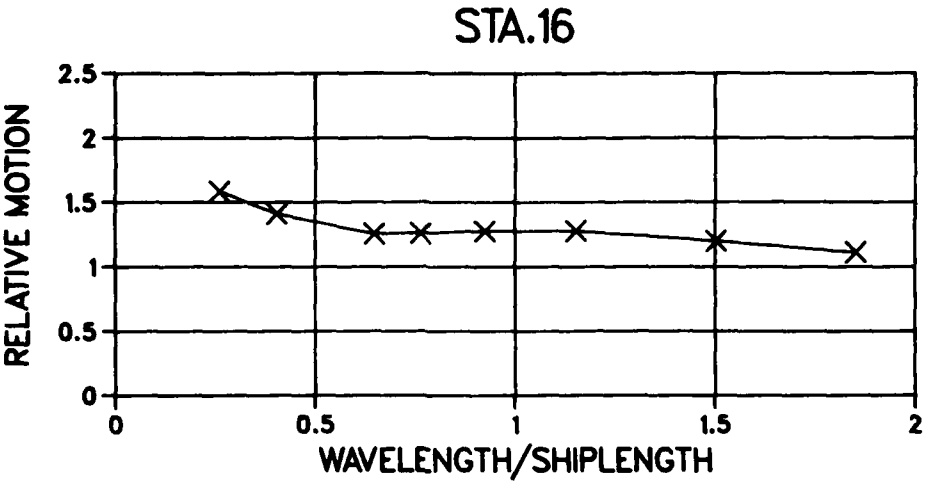

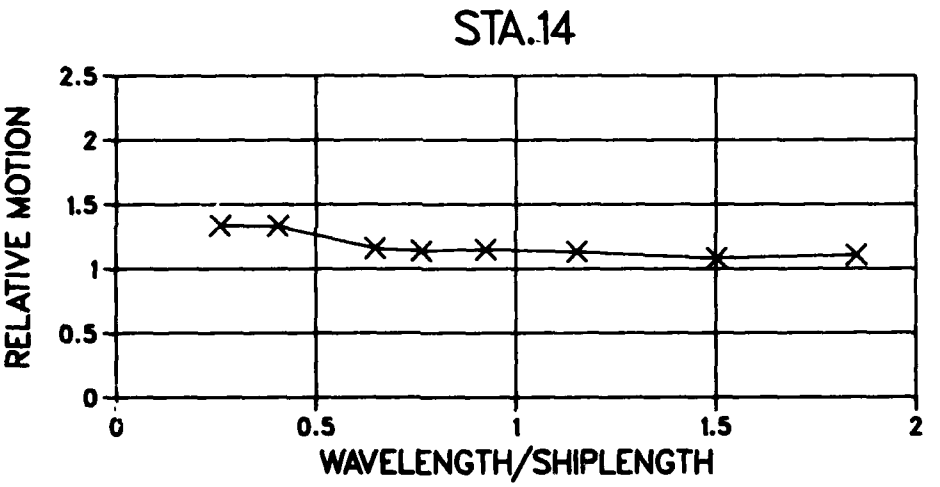

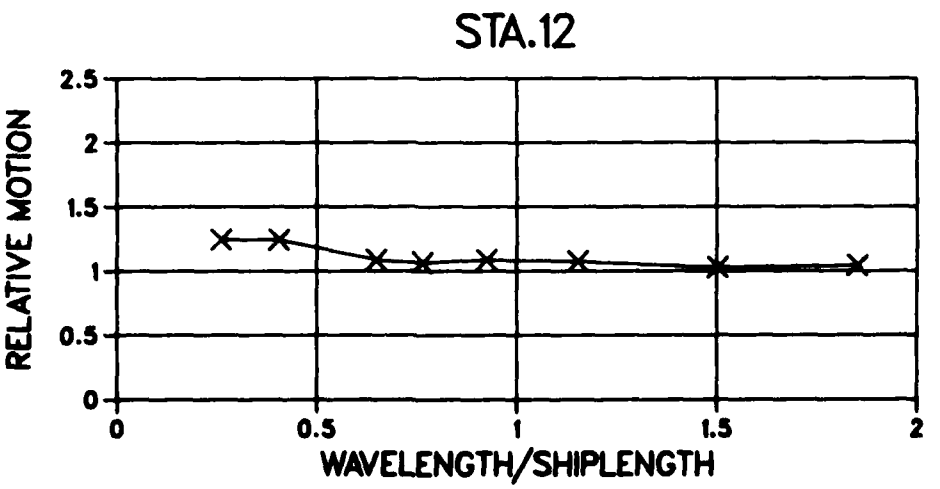

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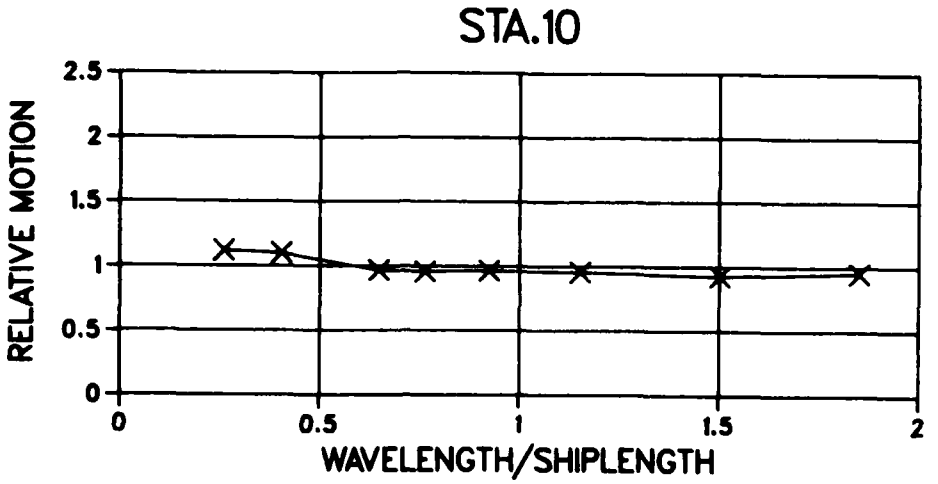

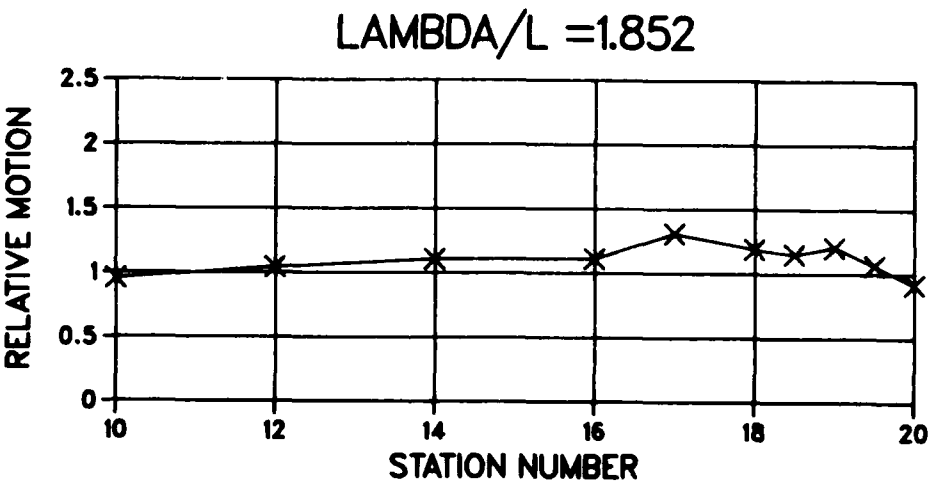

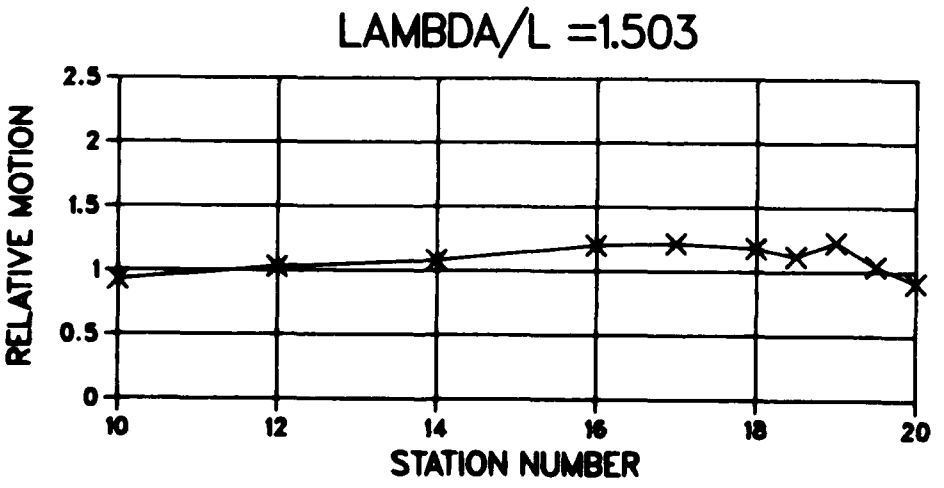

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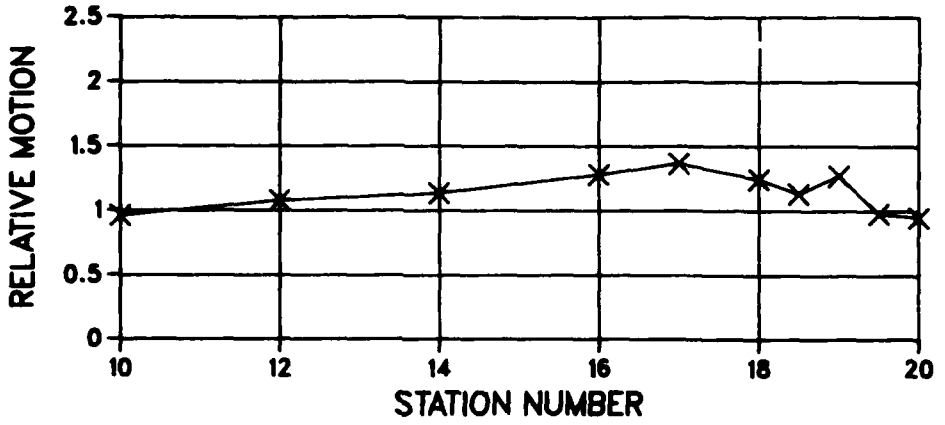

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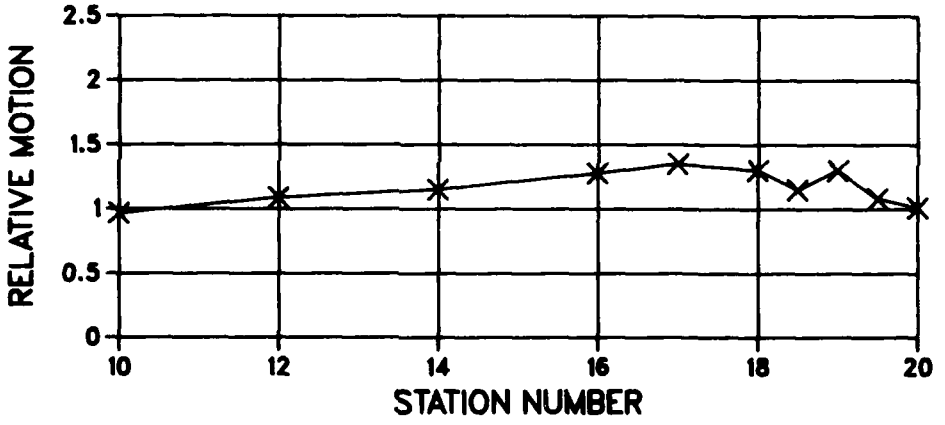

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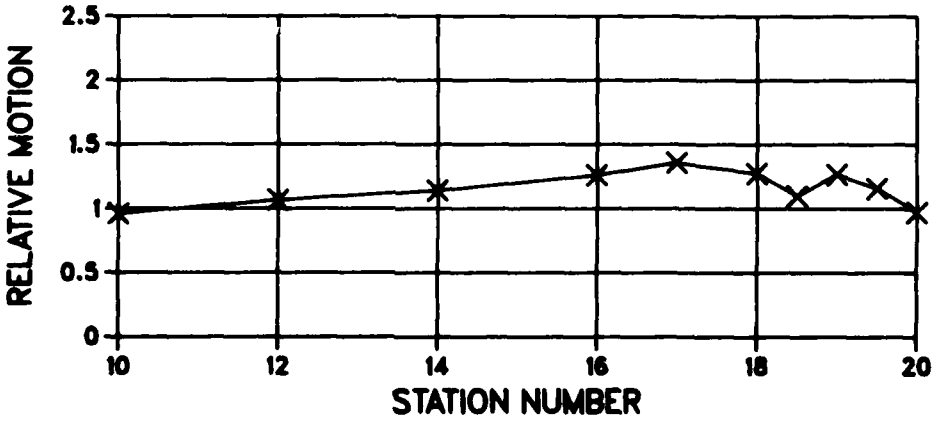

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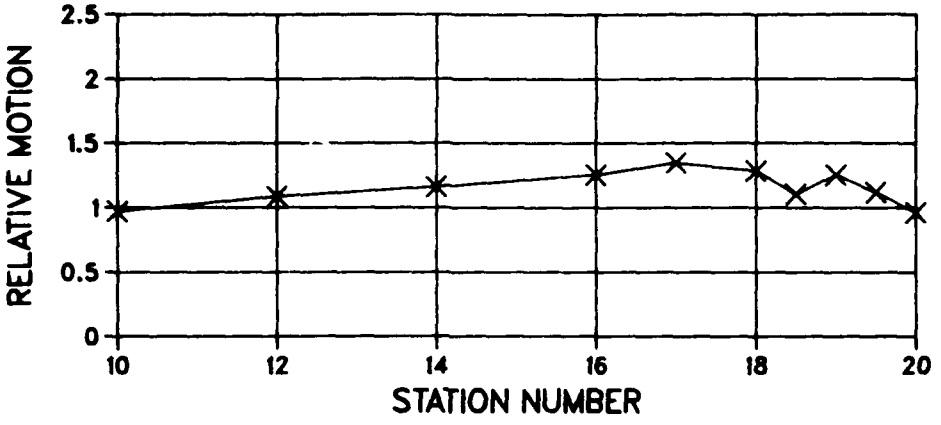

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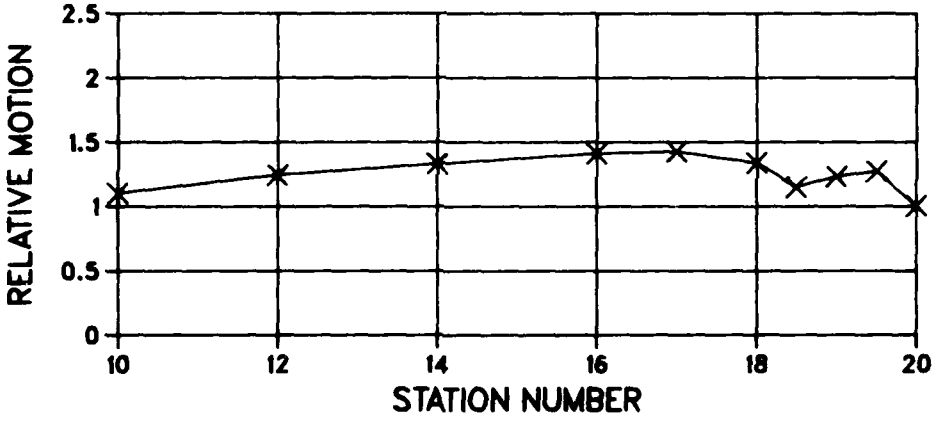

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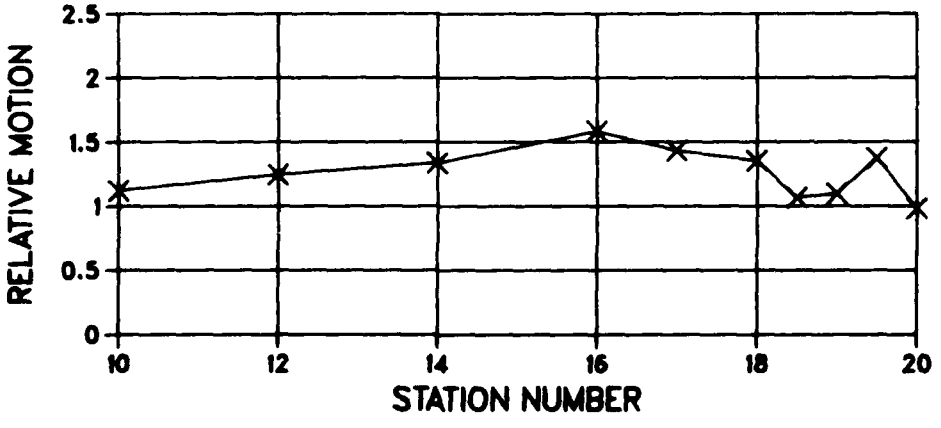

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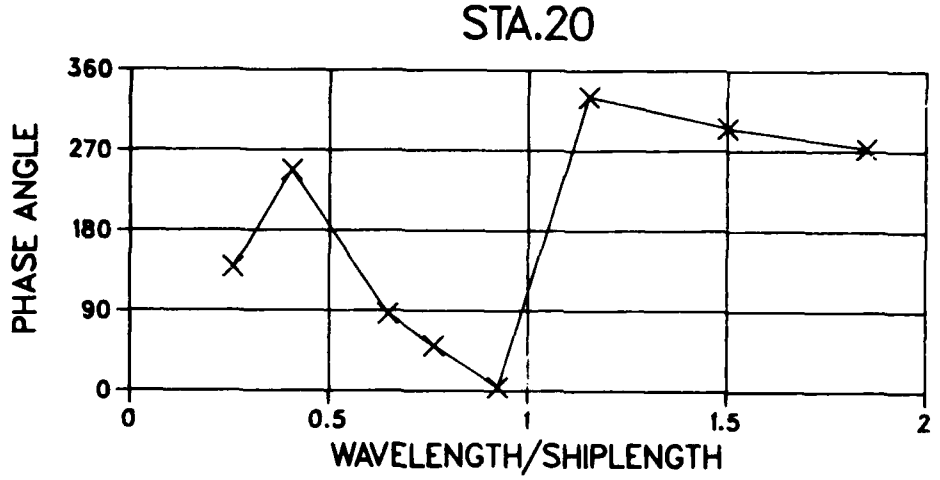

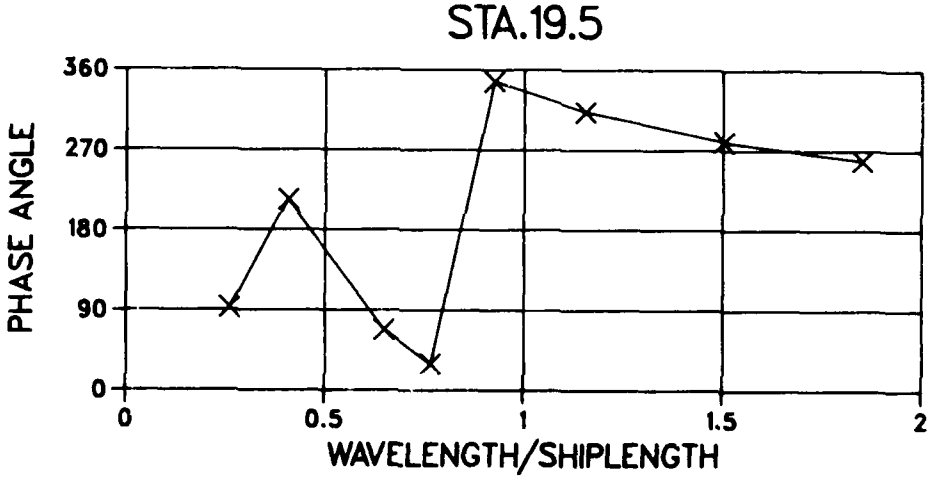

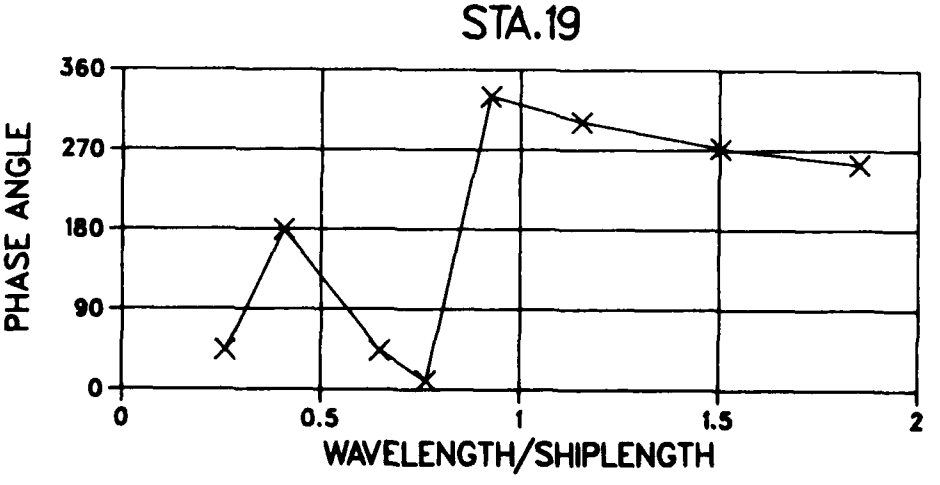

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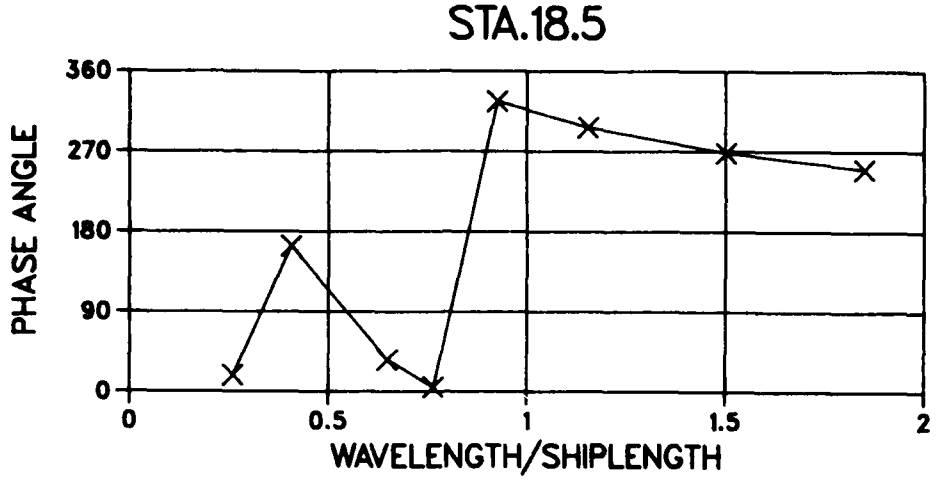

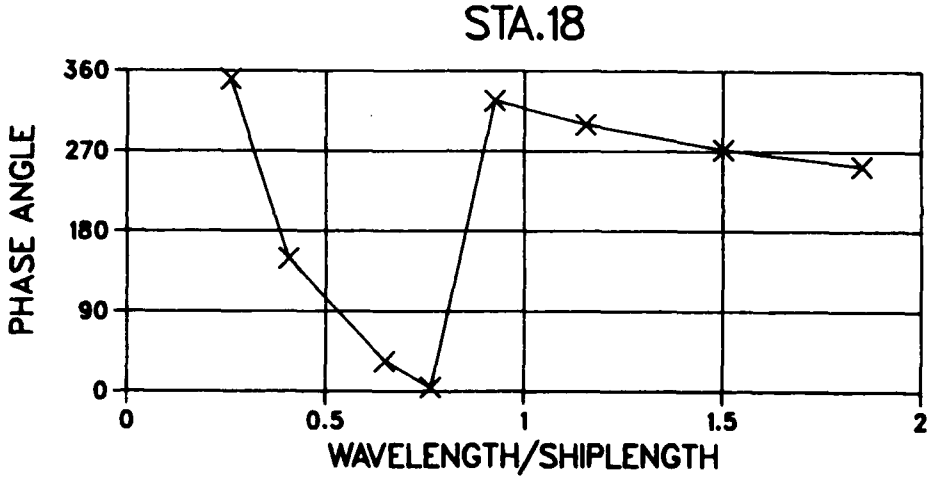

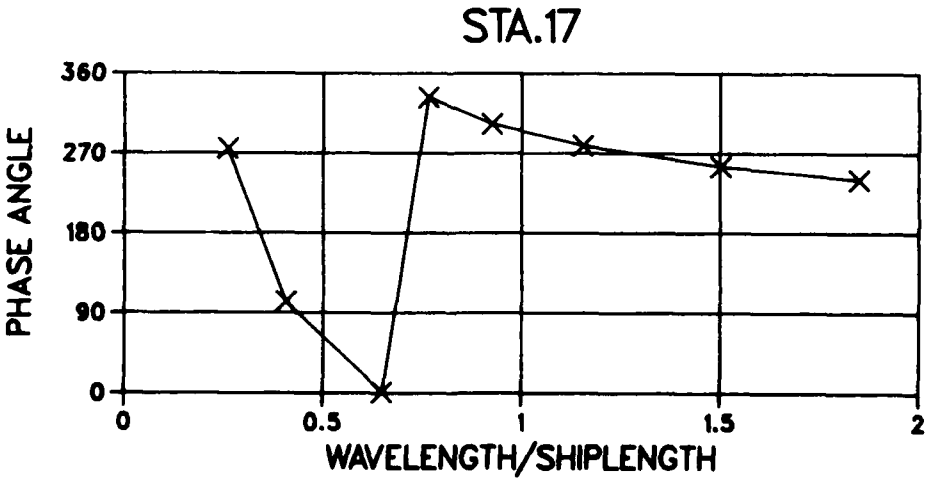

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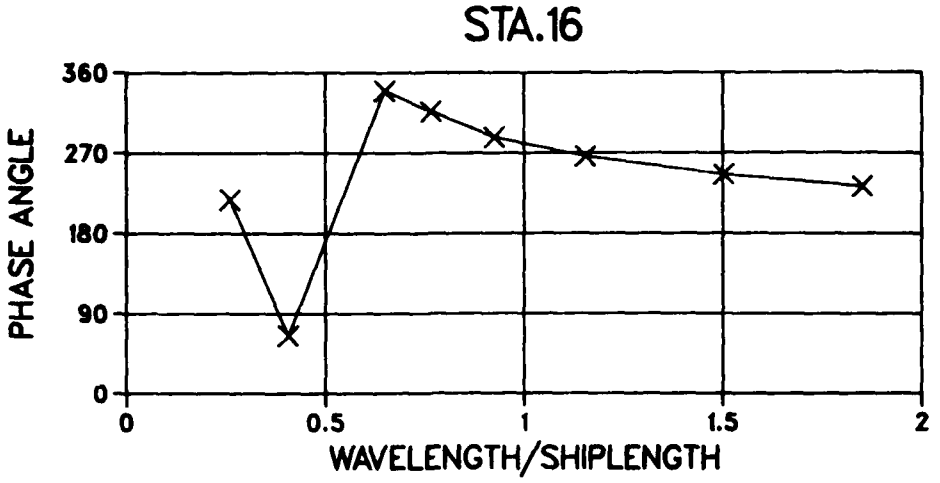

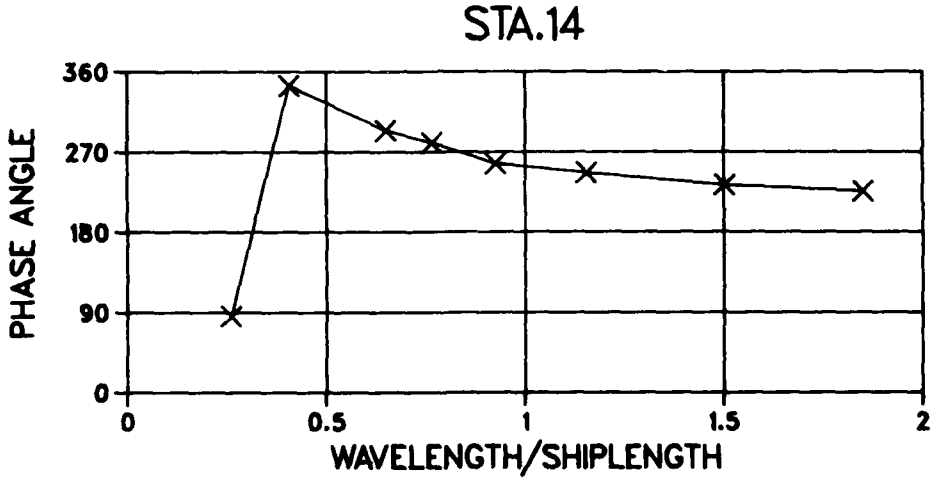

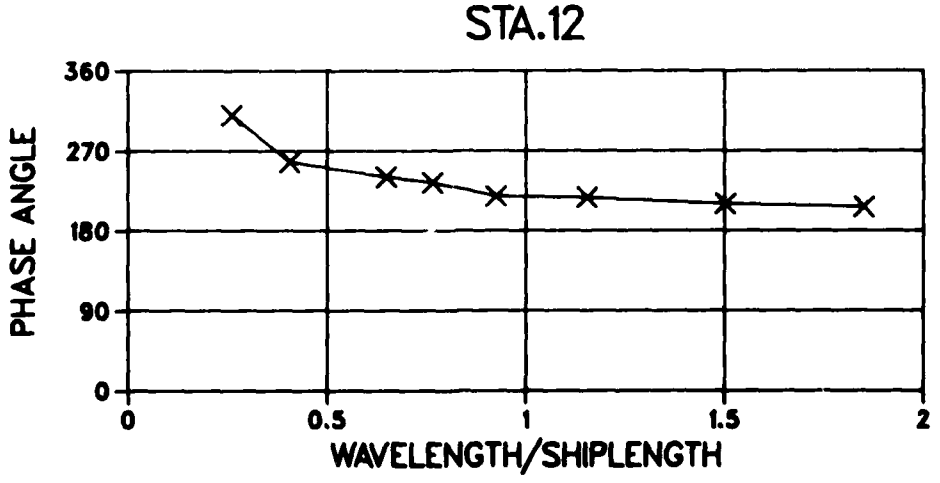

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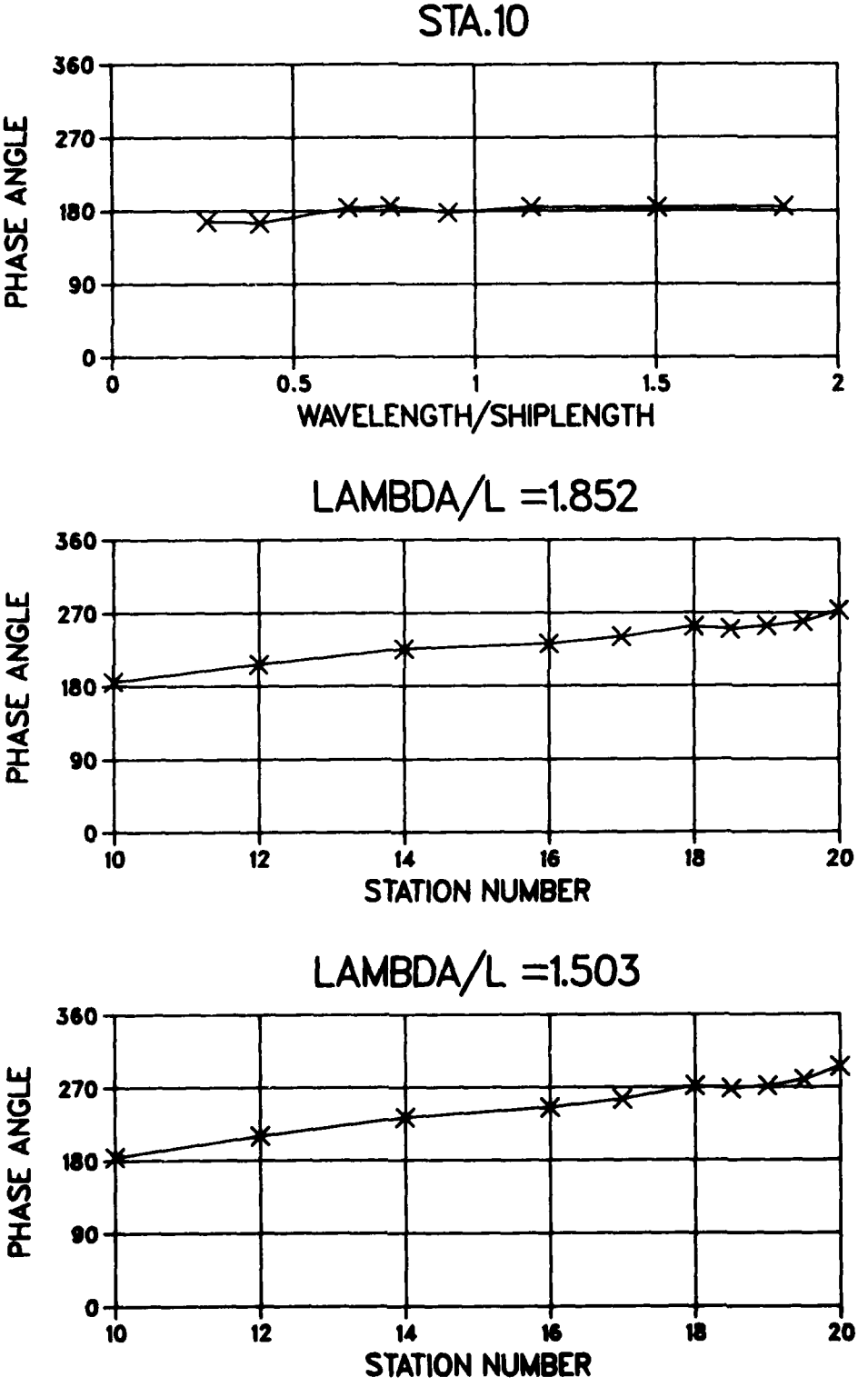

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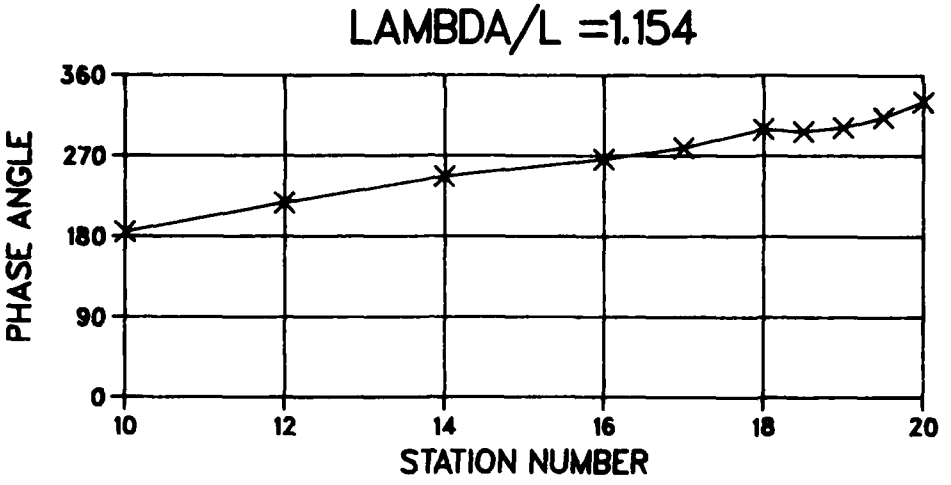

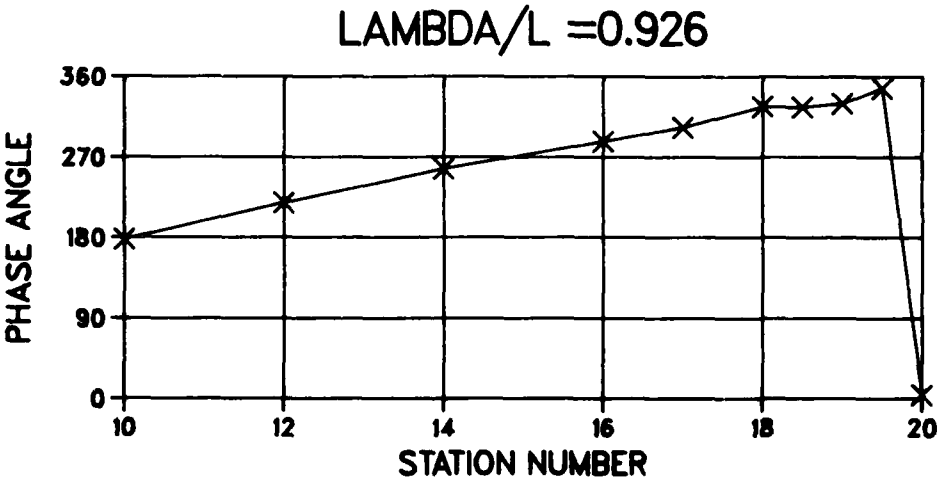

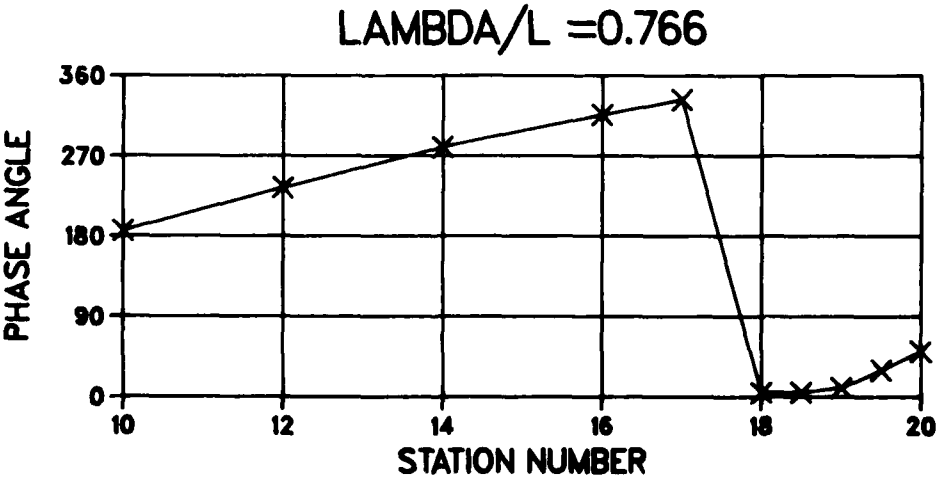

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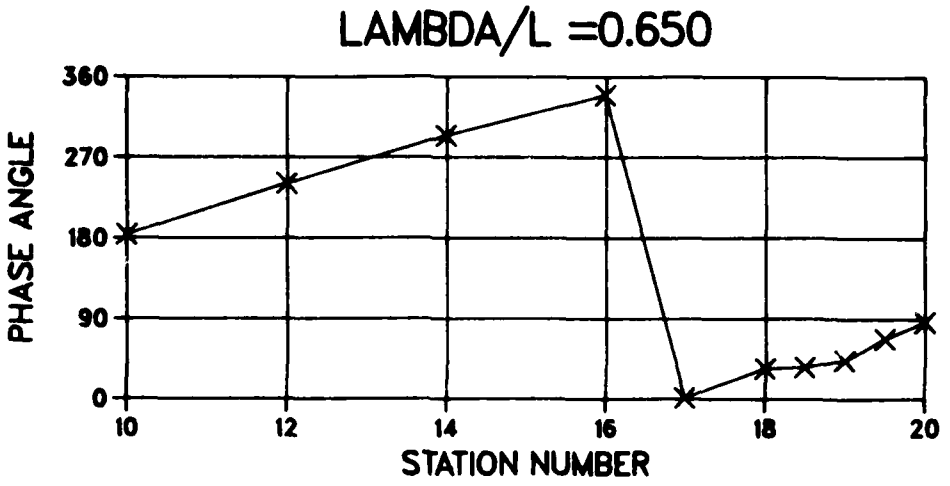
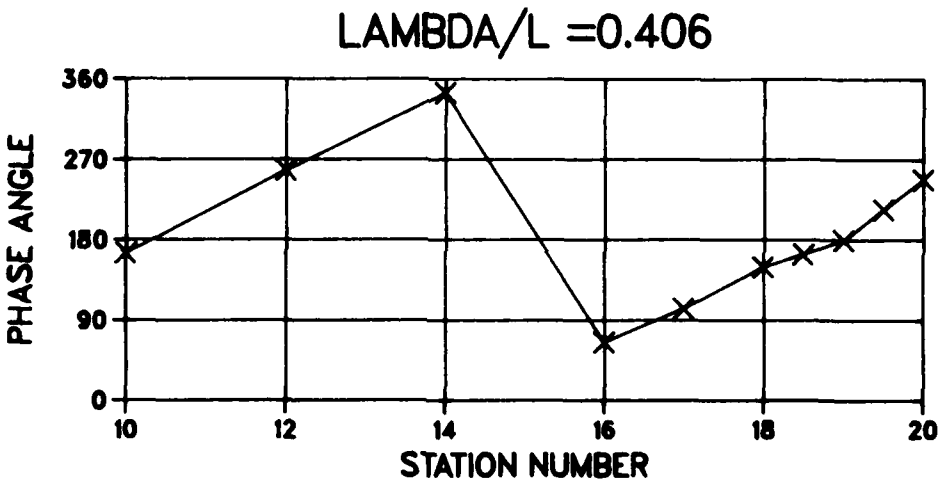
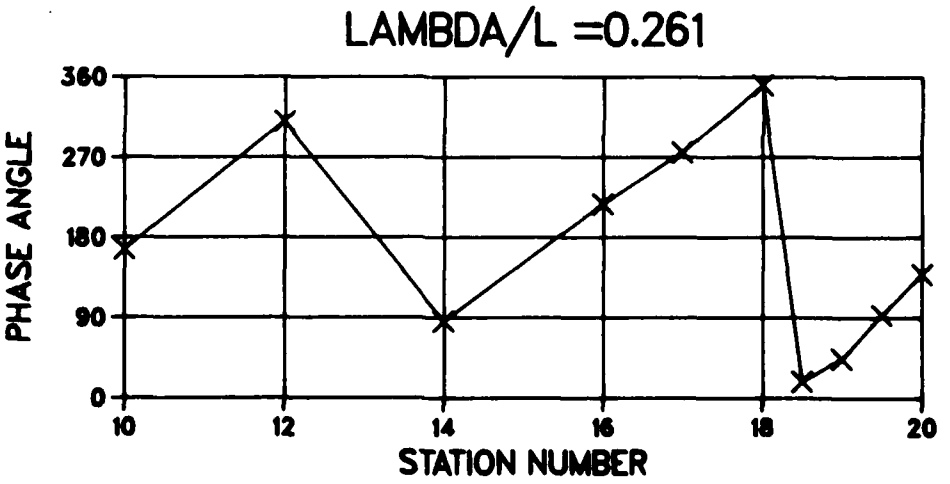
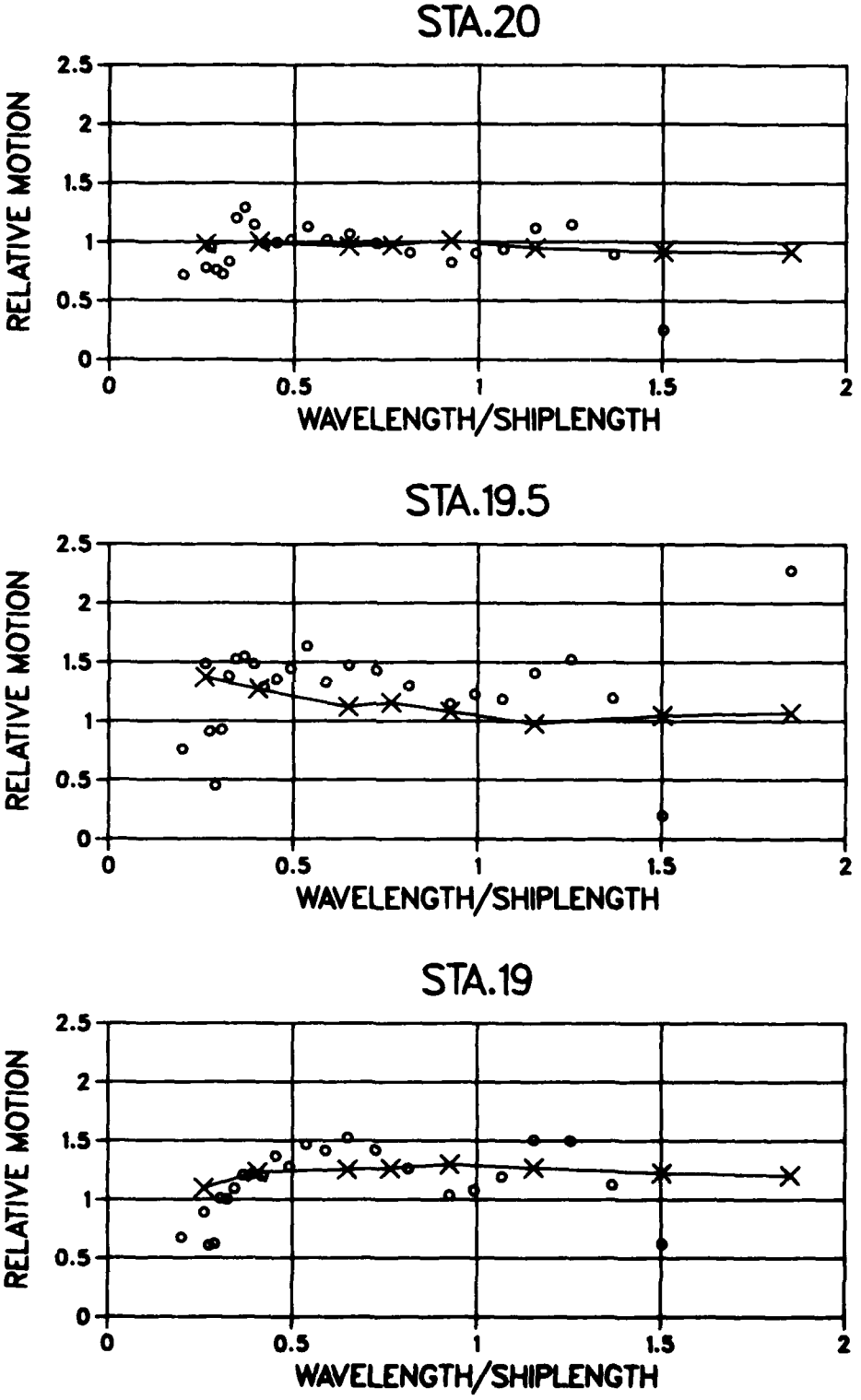


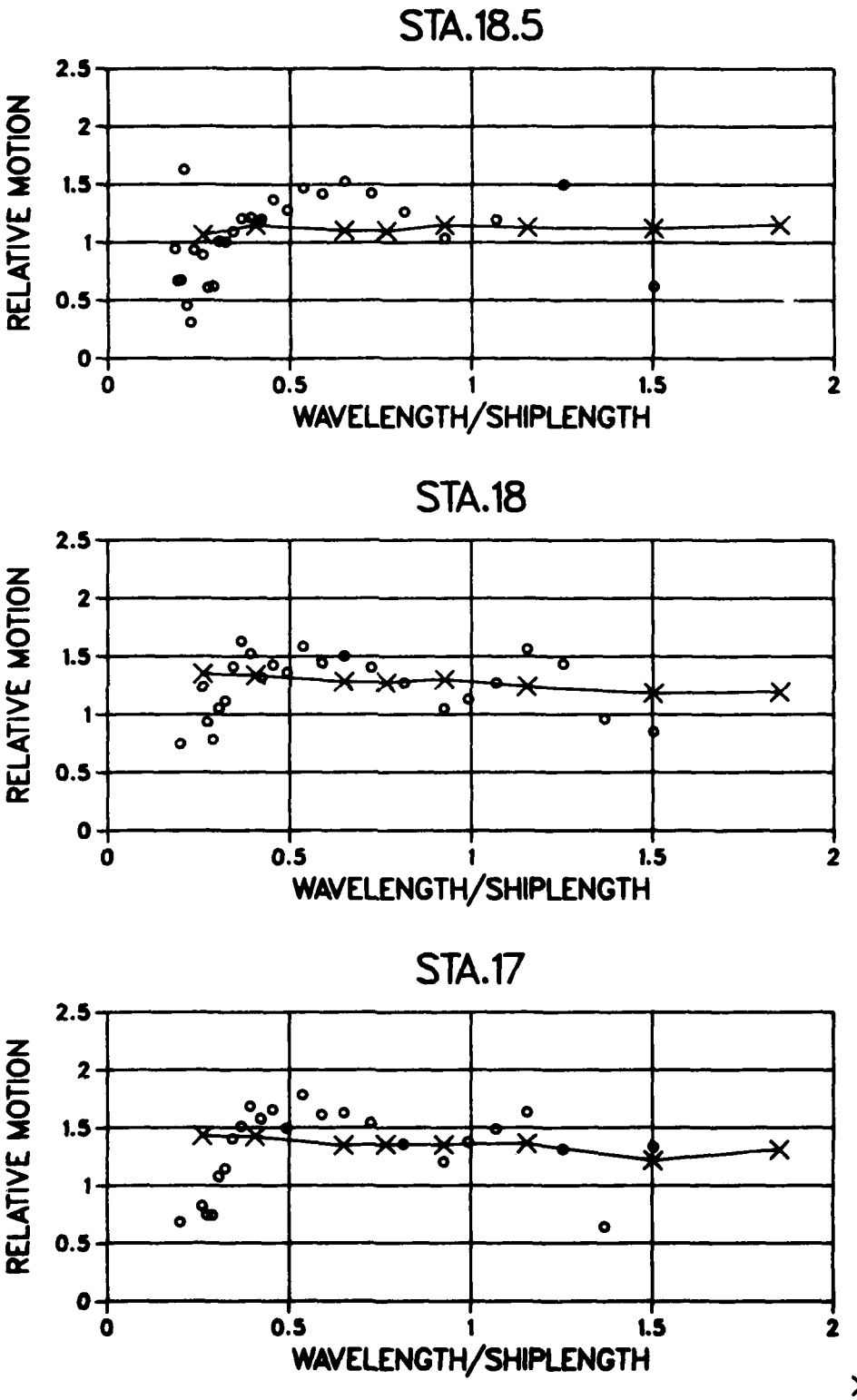




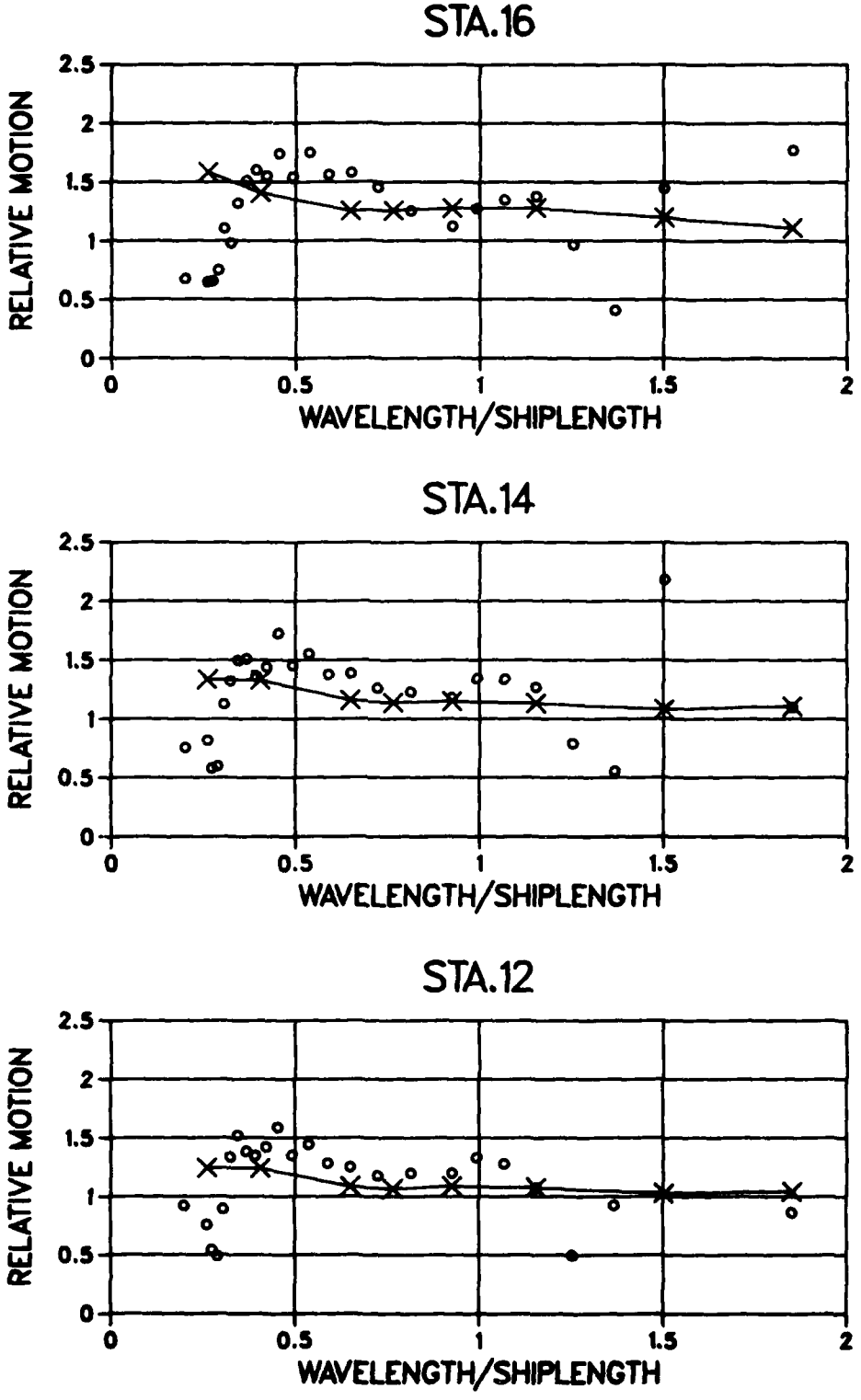
TRANSIENT TEST 1.



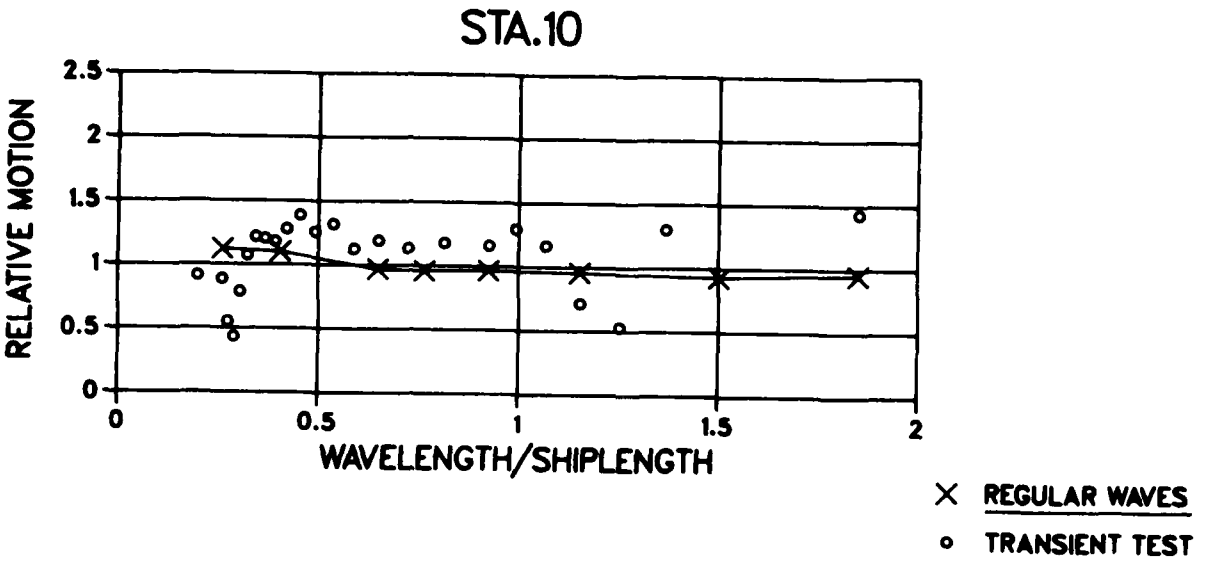
TRANSIENT TEST 1.



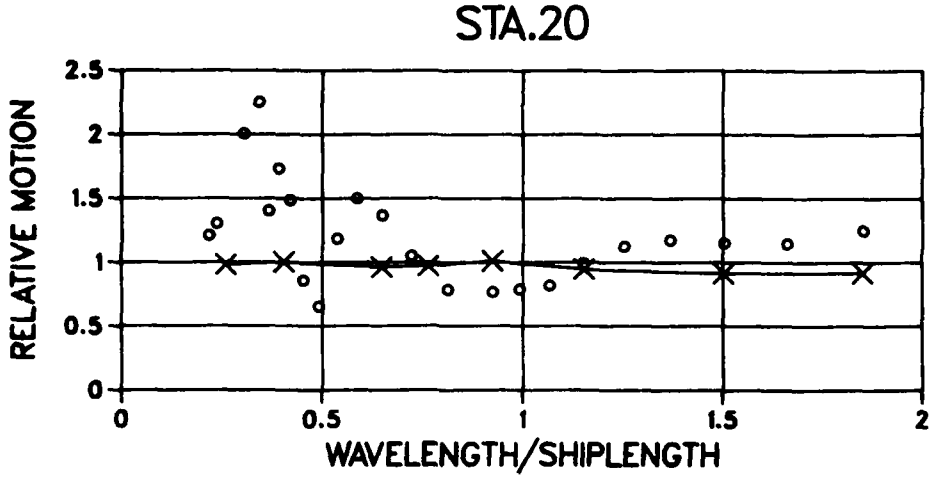
TRANSIENT TEST 1.

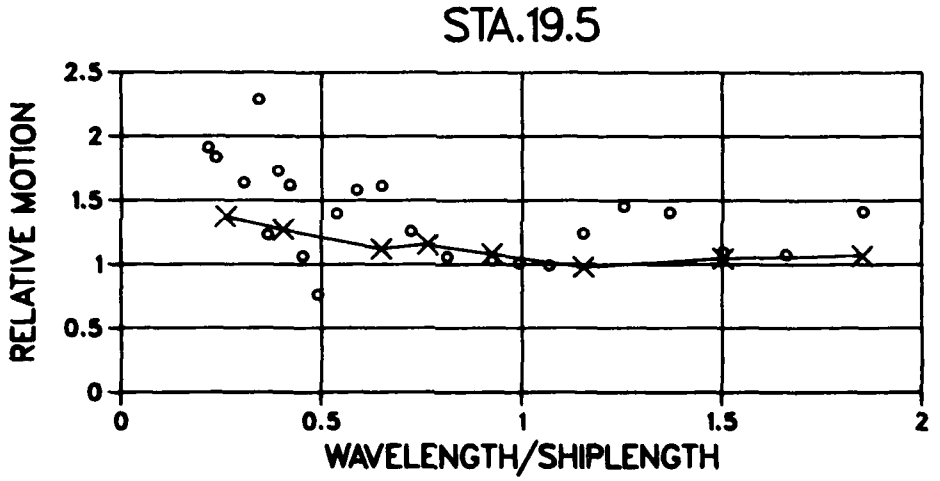


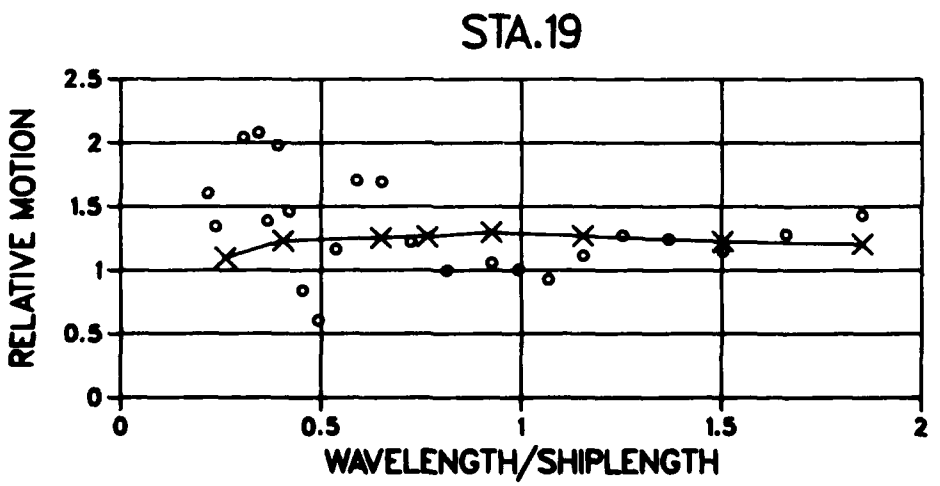
TRANSIENT TEST 1.



TRANSIENT TEST 2.



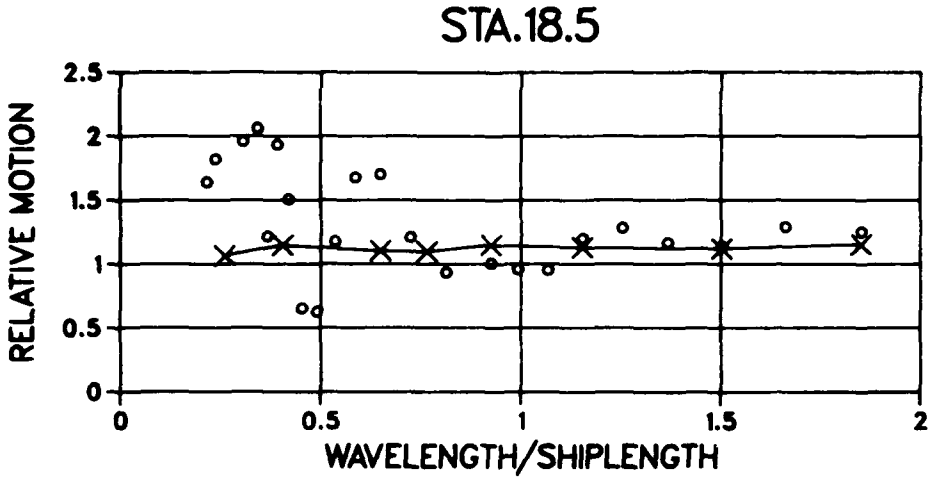


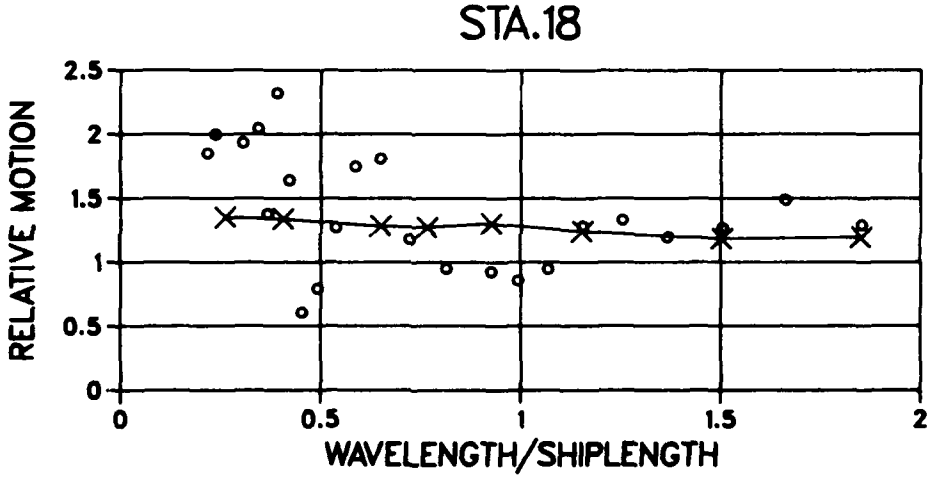


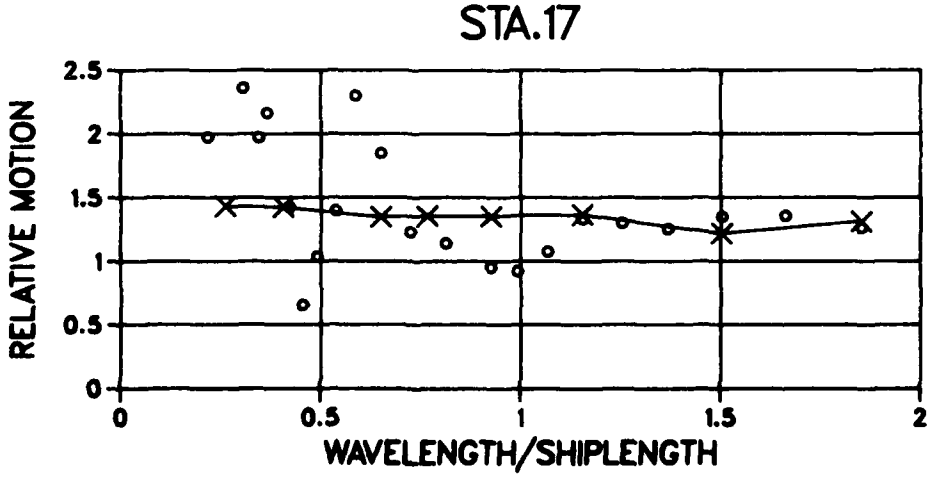
× REGULAR WAVES

o TRANSIENT TEST

TRANSIENT TEST 2.



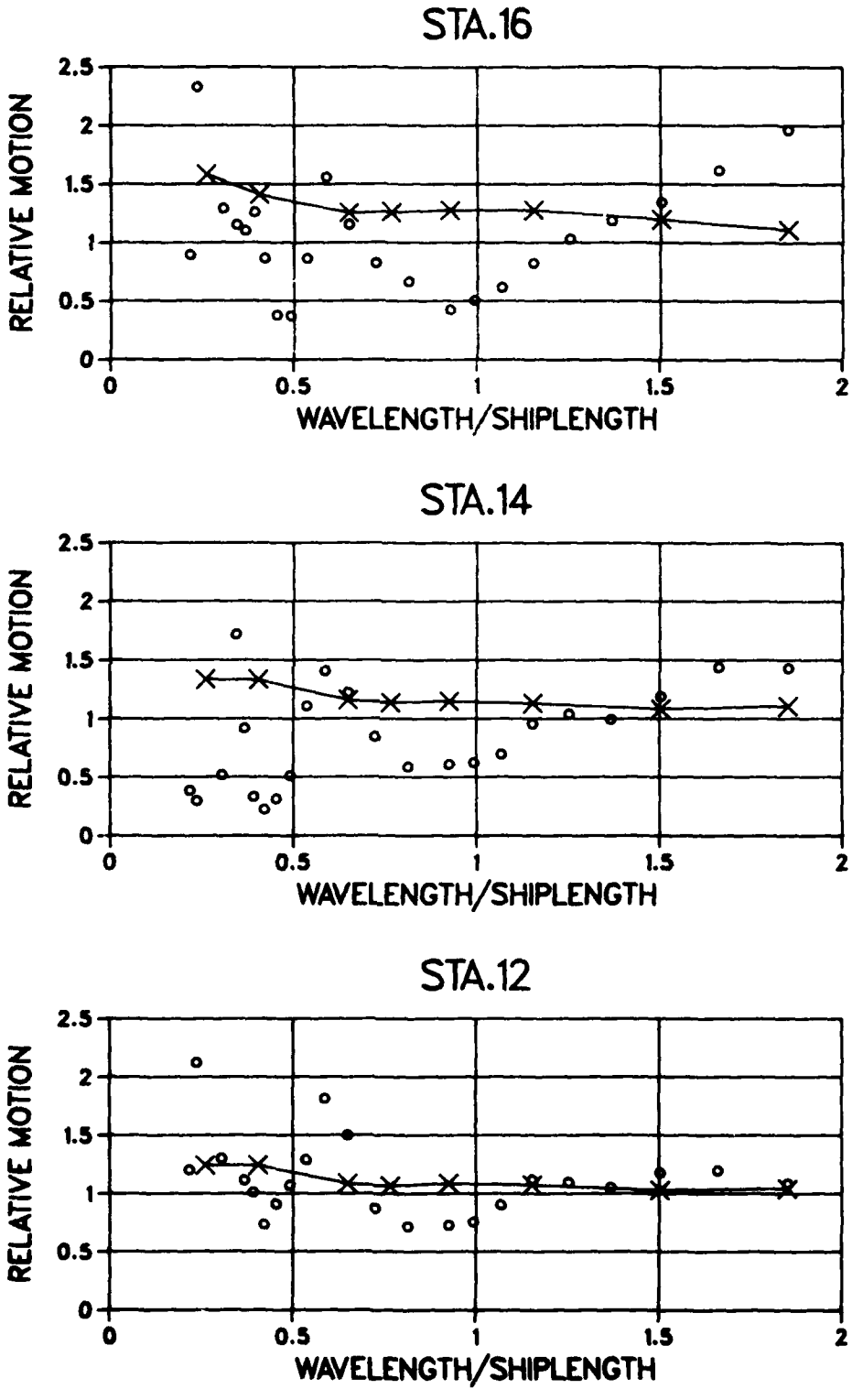




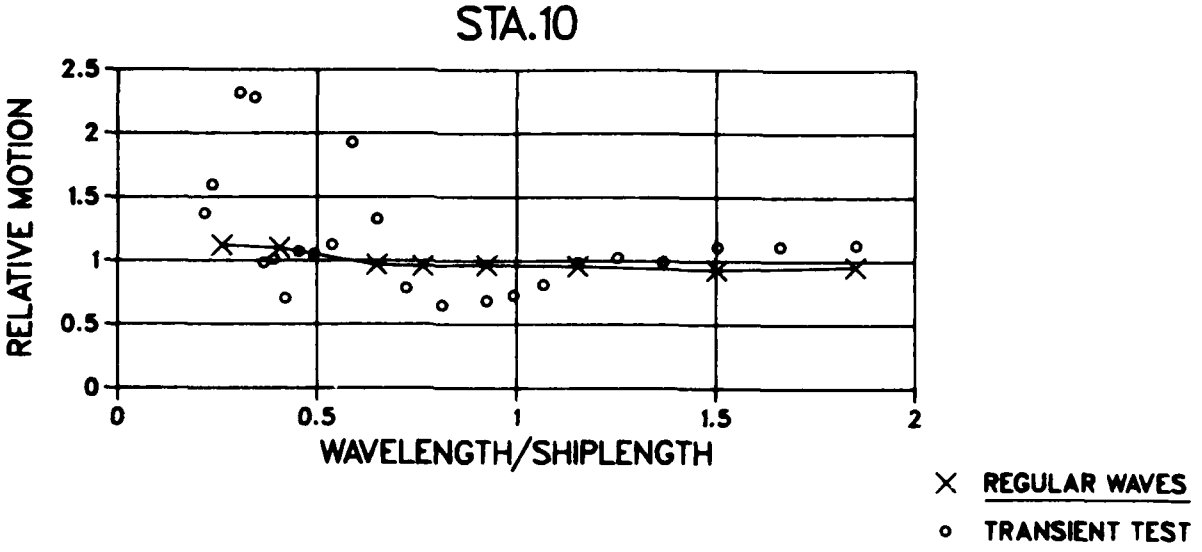
× REGULAR WAVES

o TRANSIENT TEST

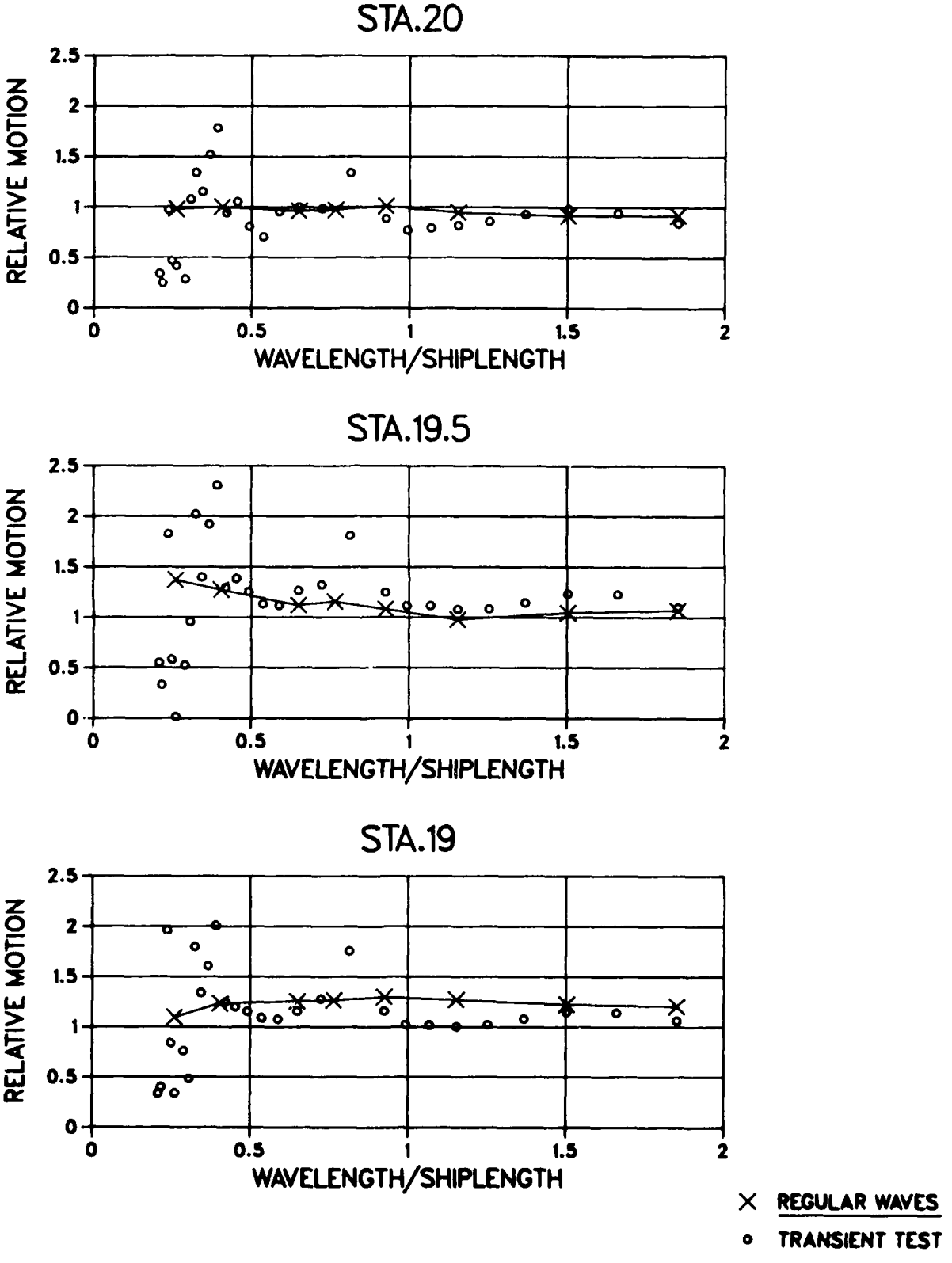
TRANSIENT TEST 2.



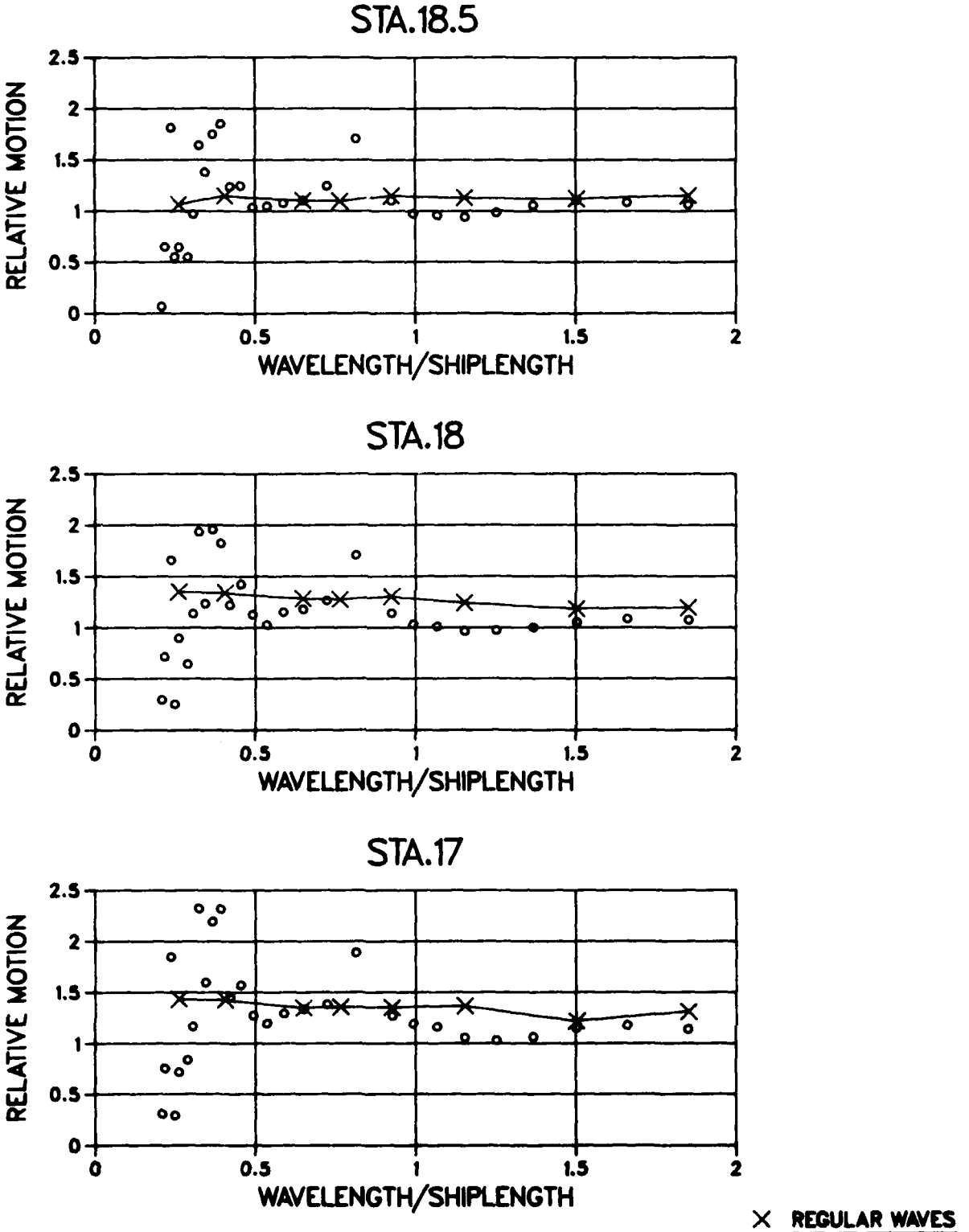
TRANSIENT TEST 2.



TRANSIENT TEST 3.



TRANSIENT TEST 3.



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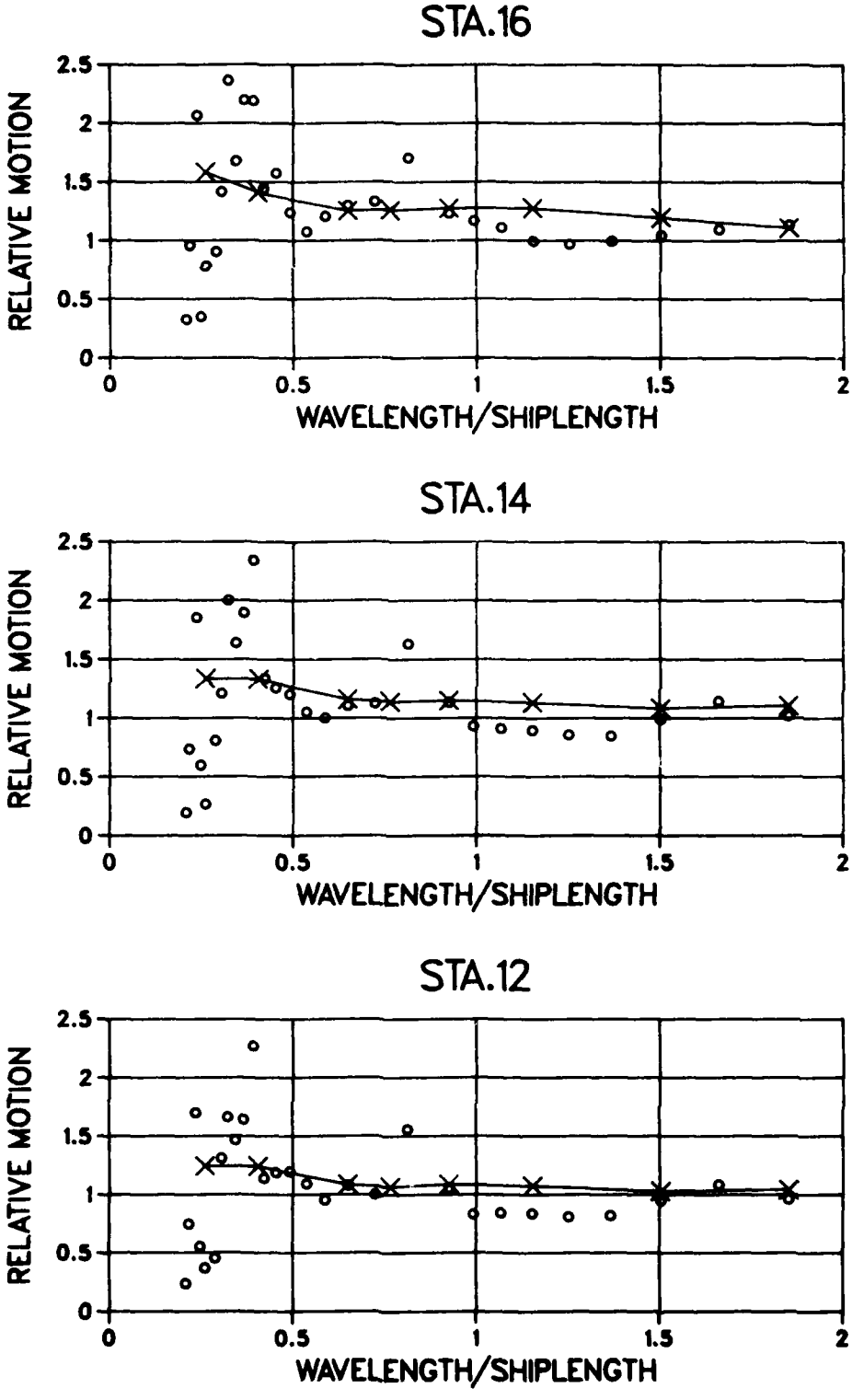

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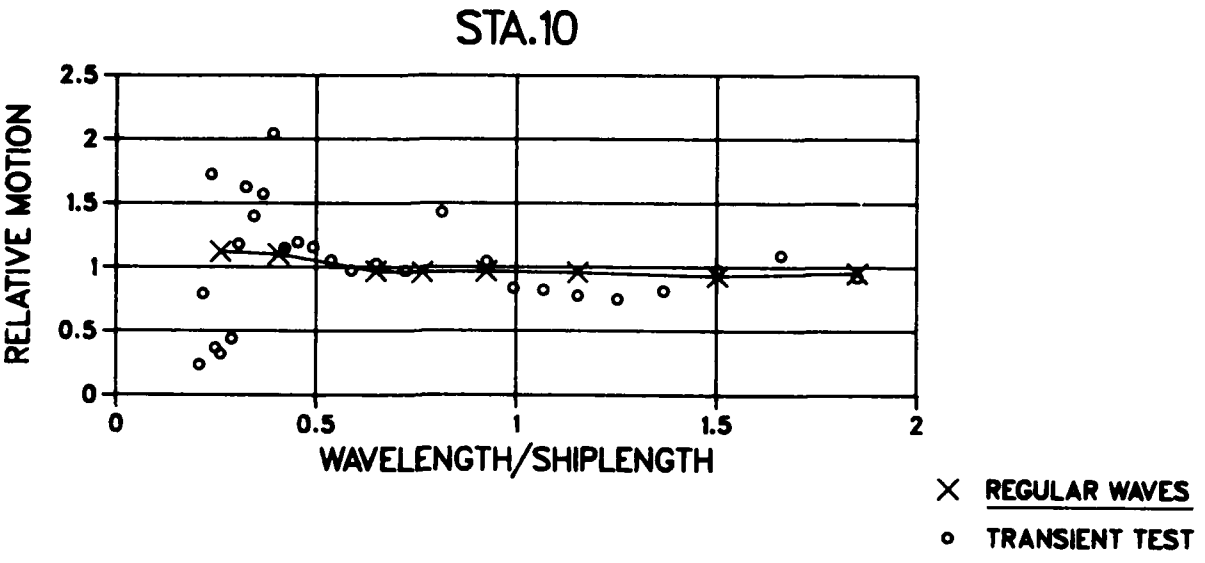

STEADY WAVE PROFILES

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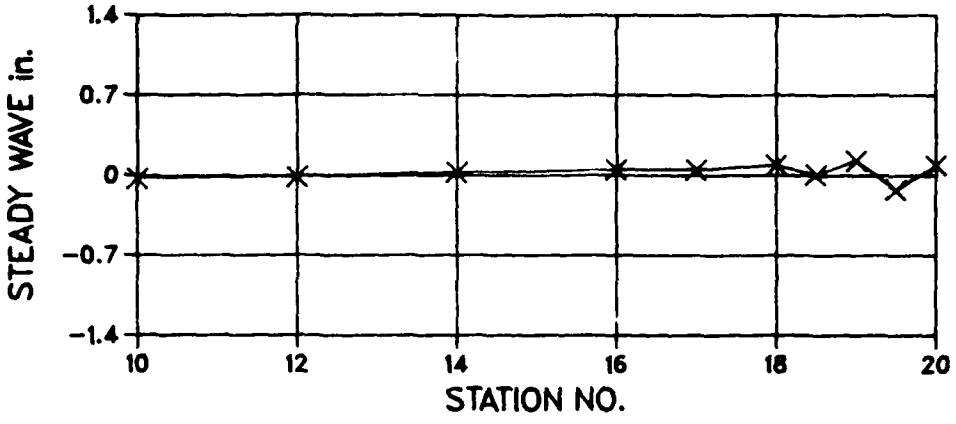

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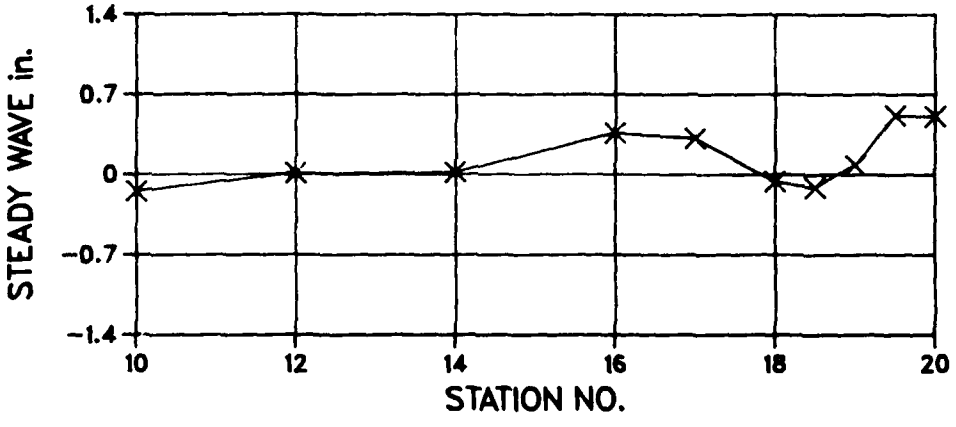

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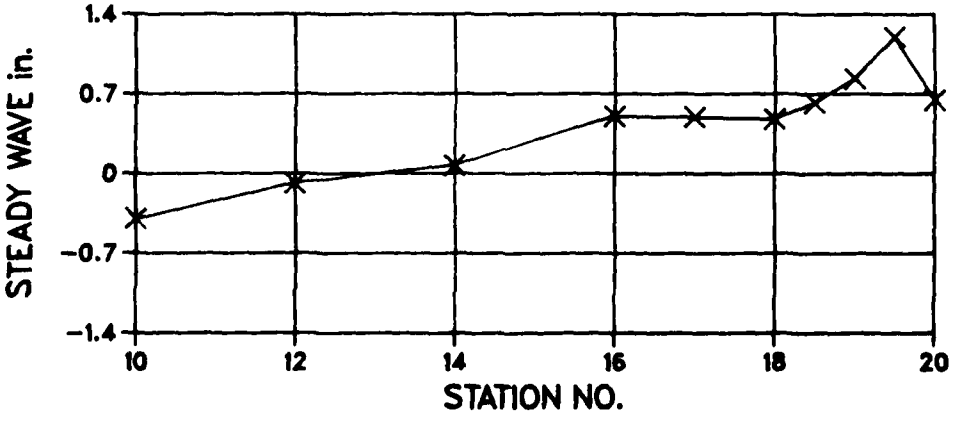

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